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SUPPLEMENT

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SUPPLEMENT,

&c. &c.

ON VEGETABLE CHEMISTRY.

It is, perhaps, easier to acquire some general ideas of Vegetable and Animal Chemistry, than to make an equal progress in the chemistry of the mineral or inorganic kingdom. The ultimate elements of vegetable and animal substances, are fewer, and are peculiarly well known—being chiefly hydrogen, oxygen, carbon, and nitrogen, with lesser proportions of calcium,* sulphur, and phosphorus. We feel on firm ground, while contemplating these hardy principles, which are not to be simplified by the most powerful agents. But, our situation is widely different, when we proceed to the investigation of such, as are indebted to the gentlest management for their existence, as distinct forms of matter. I allude, here, to certain conventional elements of vegetable and animal chemistry, which differ from each other, for the most part, merely in the proportions of the hydrogen, oxygen, carbon, or nitrogen, of which they are formed; while, in their influence on vitality, they display the opposite properties, of the most delicious food, or the most deleterious poison—of delighting, or offending, our senses in the extreme.

* The metallic base of lime.

In short, as, in the analysis of the mineral kingdom, we designate, as elementary, those substances which we cannot analyse further; so, in examining organic products, those substances which cannot be simplified, without destroying their most important characteristics, are to be viewed, as the elementary principles, by which the nature of compounds is to be understood and described.

By the distillation of vegetable substances, they are easily resolved into their ultimate elements. These, I have said, are, for the most part, hydrogen, oxygen, and carbon. Some few vegetables, exhibit nitrogen as a constituent. The alkalies, and some of the earths, or their elements, besides still more minute portions of other matter, are also generally found in vegetables. But, hydrogen, oxygen, and carbon, are, in quantity and importance, greatly predominant.

It is a marked distinction, between inorganic, and organic products generally, that the one cannot, like the other, be reproduced by art.

This incompetency in chemical skill, has caused the results of chemical analysis to be questioned. Rousseau, having heard Rouelle lecture on farinaceous matter, said he would not confide in any analysis of it, till corroborated by its reproduction from the alleged elements.

Those, who have any acquaintance with modern chemistry, will not be so skeptical. When diamond and charcoal, are burned under different bell glasses, in different portions of the same oxygen gas, and, in lieu of them, carbonic acid gas is found, in each vessel—who would hesitate to admit both substances to consist of carbon, because this element cannot be recovered in its crystalline form?

I pointed out, early in my course, the very great discordancy of the habitudes of carbon, hydrogen, and nitrogen, with caloric—that, while the two latter cannot be obtained, per se, uncombined with that cause of the repulsive, or the aëriform state, charcoal can only, by the most intense galvanic ignition, be united with it, to a sufficient degree to become aëriform.

According to Thenard, to a limited extent, the properties of vegetable substances may be inferred, from the proportions of their ultimate elements. He observes, that, no nitrogen being present, (as is most usual) if the oxygen be in a greater ratio to the hydrogen, than in water, the compound is acid. If the ratio of the oxygen to the hydrogen, be less than in water, the compound is oily or resinous. If the ratio of these elements to each other, be the same as in water, the product is of the nature of sugar, gum, or woody matter. That, where there is much carbon, there is much hydrogen—and reciprocally.

Further—vegetable products are supposed to be constituted of the binary compounds, given out during their analysis.—Thus, alcohol may be considered as constituted of one volume of aqueous gas, or steam, and one of the super-carburetted hydrogen. Again—no vegetable substance, contains enough oxygen, to convert its hydrogen and carbon into water and carbonic acid.

As substances are either acid, resinous, or oily, or of an intermediate quality—it may be proper to treat of them, successively, as they fall under those general characteristics.

It does not appear, that any vegetable matter is susceptible, per se, of the gaseous state. The volatility of scented, or aromatic emanations, is, no doubt, like that of camphor or turpentine, due to a solution of the matter, of these emanations, in atmospheric air.

When ignited in close vessels, vegetables yield water and certain volatile oils—as, for instance, oil or spirit of turpentine, which, as well as the water, were existing in the vegetable matter as water and oil. A further distillation produces carbonic, pyrolignous, or acetic acid, carbonous oxide, with bituminous matter, or essential oils, formed by the union of the hydrogen and carbon, in different proportions—and which are more volatile, in proportion as hydrogen predominates. By further ignition, the oils and bitumen, thus obtained, are converted into carburetted hydrogen—a depo-

sition of carbon, being a necessary concomitant of the change. —In proportion to the extent to which the hydrogen is rarefied by heat—its capacity to suspend the carbon, is diminished.

The oxygen in the compound, by uniting with the hydrogen and carbon, gives rise to the water, and acetic and carbonic acids, and carbonous oxide, which are formed during the process.

It is evident, that these results originate from the superior volatility of the hydrogen and oxygen, which causes them to pass off into the aëriform state, with such portions of the carbon as they may, under these conditions, retain.

The experiments of Sir James Hall, show, that vegetable matter, subjected to great compression, as well as heat, is converted into a bitumen, analogous to that of mineral coal. —Under these circumstances, the heat destroys the organic structure, but does not sever the constituents of many bodies, which would be otherwise partially dissipated. Exposed to heat in the open air, it were almost unnecessary to say, that hydrogen, oxygen, and carbon, must yield water and carbonic acid only. These are the only products of hydrogen and carbon, when burned, where there is an ample supply of oxygen.

The ratio of the quantity of water, acetic acid, and carbonic acid, and other incombustible matter, (afforded by a destructive distillation,) to that which is of an opposite character, varies of course with the nature of the substance operated on; and hence the employment of resinous wood, resins, and bituminous coal, for illumination.

The two other substances, classed under the name of supporters of combustion—iodine and chlorine—act on vegetable matter, by their affinity to one of its principles only. For carbon they have little affinity—and, exerting but a feeble attraction to oxygen, under any circumstances, in ordinary cases display none. Where there is much carbon, in intimate combination, as in wax and resinous substances, chlo-

rine does not act, until, by heat, their hydrogen is separated more or less from the carbon. Where water is present, its decomposition is always slowly effected by chlorine, especially when any matter attractive of oxygen may be present, as in the case of vegetable colouring matter. Hence the efficiency of chlorine in bleaching.

Iodine unites with starch, without decomposing it—producing a deep blue.

The metals of the alkalies, destroy vegetable matter containing oxygen as an essential constituent, by combining with this principle, and liberating hydrogen. Fluoric, fluoboric, and sulphuric acids, at moderate temperatures, destroy organic matter, by their attraction for water; in which respect, they evidently do not act as acids, but have an effect analogous to the dry alkaline hydrates, and desiccated chlorides. In like manner, sulphuric acid, hydrate of potash, and the chloride of calcium, absorb the elements of water from alcohol, and discolour it, by evolving a carbonaceous matter.

The muriatic acid acts feebly on organic substances; but, so far as it does act, it appears also to operate by its affinity for water.

The nitric acid, on the other hand, has no other effect, than to impart oxygen—giving rise to the same products as combustion; a result, which ought not to excite surprise, as this acid is, in effect, composed of atmospheric elements, condensed into the fluid form, and containing an excess of that principle which is the most active. Owing to the volatility of nitric acid, many substances cannot be completely oxygenated by it, unless after several distillations. Repeatedly distilled from sugar, it produces malic acid first, and then oxalic acid, and finally water and carbonic acid. These ultimate results, are inevitably consequent to the ignition of the nitrates with dry vegetable substances—as, in this case, the alkali detains the acid, until the heat is adequate to produce a rapid reaction.

OF THE PROXIMATE ELEMENTS OF VEGETABLE MATTER.

OF EXTRACT.

In Henry's Chemistry, and other compilations, a substance is mentioned, under the name of Extract,—a vague and improper appellation, to be given to any peculiar principle. It does not appear certain, that chemists generally coincide, in designating any principle by this name.

The residuum of an evaporated infusion of saffron, is considered as a specimen of Extract, by some chemists.

OF MUCILAGE, OR GUM.

The substance next spoken of, by the author of the work in question, is one, universally admitted to exist. I mean Mucilage, which, when inspissated by evaporation, is called Gum.

Gum, as obtained from different plants, differs in some minute particulars. Its general characters must be familiar to every body, as observed in the infusions of linseed, or gum arabic in water. It is neither sweet nor sour. In ether, or alcohol, it does not dissolve. The more powerful acids, when diluted, dissolve gum; when they are concentrated, it is decomposed by them, in consequence of their avidity for hydrogen and oxygen, in the form of water. It is likewise soluble in alkalies, and may be precipitated, unchanged, by acids.

Cerasin, is an appellation given to a species of gum, obtained from the cherry tree, or the Astragalus Tragacantha. Of this species, gum tragacanth is a fair specimen. The mucilage of linseed, is peculiar, in not being susceptible of precipitation by silicated potash: also, in yielding white flocks, when mixed with alcohol; whereas the same agent, merely renders solutions of gum milky.

Sub-acetate of lead, throws down a precipitate, and so does deuto-chloride of tin. Nitrate of mercury produces a slight precipitate.

OF SUGAR.

Sugar, so well known in its ordinary form, differs but little from gum or starch, in its ultimate elements. It is distinguishable into two kinds, of which only one is crystallizable. Hence portions of honey, of syrup, or of grape juice, (as seen in raisins,) may be observed to form candy, while another portion remains glutinous. Melasses is the uncrystallizable portion of the juice of the sugar-cane. The saccharum of germinated or malted grain, also that of liquorice, is of this kind.

Sugar is soluble in about an equal weight of cold water.—Above a boiling heat, it becomes, per se, a fluid, dissolving in its water of crystallization. Alcohol dissolves one-fourth of its weight. Lime and sugar, reciprocally, increase their respective degrees of solubility. Sugar decomposes some metallic salts, by abstracting the whole of their oxygen and acid; reviving the metal, as in the instance of the sulphate of copper. In others, it acts by removing a portion of the oxygen only, as in the case of the acetate of the same metal. With oxide of lead, it forms an insoluble compound, called saccharate of lead by Berzelius.

OF MALIC AND OXALIC ACIDS.

Subjected to the action of strong nitric acid, sugar yields either Malic Acid, or Oxalic Acid—according to the quantity of acid employed, and the duration of the exposure.

I have obtained Malic Acid, and, afterwards, on adding more acid, have, by a repetition of the process, procured Oxalic Acid.

Malic Acid derives its name from the apple, as in this fruit it predominates, as well as in gooseberries, currants, and other similar fruits. It may be had pure, (by a process analogous

to that by which Scheele procured the citric acid,) by saturating lime with apple juice, and decomposing the mallate of lime by sulphuric acid.

Oxalic Acid derives its name from the Oxalis Acetosella. It is crystallizable—not very soluble—and takes lime from all its combinations.

This acid combines with potash in three proportions—the quantity of acid being as 1, 2, and 4. Hence the appellations, oxalate, binoxalate, and quidroxalate.

The salt of sorrel is a binoxalate, consisting of one atom of potash, with two atoms of oxalic acid.

Oxalic Acid is a poison. Magnesia, or bicarbonated alkalies, are the best antidotes. In default of the bicarbonates, a solution of pearlash, or an infusion of wood-ashes, or even a solution of soap, should be ventured.

Oxalic Acid is no more the acid of sugar, than of various other substances from which it may be made.

Malic Acid, and Acetic Acid, are no less the acids of sugar, than the Oxalic—as they are both produced from sugar by the same process.

OF SORBIC ACID.

An acid is found in the berries of the mountain ash, to which this name has been given. It is now alleged to be identical with the Malic acid.

PRINCIPAL NATIVE VEGETABLE ACIDS.

The following are mentioned, by Henry, as the principal native acids:—Citric, Gallic, Malic, Sorbic, Tartaric, Oxalic, Acetic, Prussic, Phosphoric.

OF CITRIC ACID.

The name of Citric Acid discloses its origin. It exists in the lime and lemon, in union with mucilage and the malic

acid. This combination is so intimate, as to render it impossible to separate the acid, without first uniting it with some other matter. Alcohol is the most ready agent for this purpose, as it combines with the acid, and precipitates the mucilage. The alcoholic solution, thus obtained, does not yield crystals, even after evaporation, re-solution in water, and evaporating the latter fluid. Scheele pointed out, that the most efficient mode of obtaining this acid pure, is to saturate the juice of lemons, with chalk or whiting, and decomposing the citrate of lime, thus formed, by sulphuric acid, duly diluted.

OF GALLIC ACID, OR ACID OF THE GALL NUT.

An aqueous infusion of galls, yields Gallic Acid in crystals, by exposure. Pounded galls yield it by sublimation.

The infusion of galls contains the tanning principle, called tannin, and Gallic Acid. Muriate of tin precipitates the tannin—a portion of the oxide remaining united to the acid.—This oxide may be precipitated by sulphuretted hydrogen, and the Gallic Acid crystallized by evaporation.

Fresh precipitated earth of alum, will also take the tannin and other matters from a solution of galls, allowing the acid to be crystallized by evaporation.

There is some obscurity and contradiction, with respect to the properties of this acid. Henry informs us, that it precipitates most metals, besides the aqueous solutions of lime, barytes, and strontites, and the acid solutions of glucine, yttria, and zircon; while Thenard alleges, that among all the salts, those of the deutoxide and tritoxide of iron, are alone decomposed by pure Gallic Acid. It is when united to tannin, that it displays the powers ascribed to it by Henry—as it then precipitates solutions of copper, tin, lead, titanium, iron, mercury. We are indebted to this combination, of tannin with Gallic Acid, and tritoxide or red oxide of iron, for ink.

OF TARTARIC ACID.

The Tartaric Acid, named from tartar, (or the residuum of wine, whence it is principally obtained,) is found in many vegetables. In the tamarind, it predominates; and it forms an exudation, on the berries of the sumach. It exists in the lees of wine, in the state of super-tartrate of potash; and, when freed from impurities, is sold in the shops under the name of cream of tartar. When, to 24 parts of this salt, 13 of sub-carbonate of soda are added, Sal Rochelle is produced; and, in like manner, emetic tartar, by saturating the excess of tartaric acid with oxide of antimony. Tartaric Acid is procured from cream of tartar in fine crystals, by saturating the excess of acid with chalk, and decomposing the precipitate by diluted sulphuric acid. The neutral tartrate left, may be decomposed by quick lime, or chloride of calcium, and the resulting tartrate of lime, will yield the acid in the same way as the precipitate by chalk.

OF BENZOIC, PRUSSIC, PHOSPHORIC, AND KINIC, ACIDS.

In addition to the acids already spoken of, we ought to notice, as important among the vegetable acids—the Benzoic, the Prussic, the Phosphoric, and Kinic, Acids. Others are mentioned by Henry, which are not sufficiently striking, to make it important to remember them. The Prussic and Phosphoric acids, more appropriately the products of animal matter, are at this time merely worthy of attention, as being among those of vegetation.

It appears, that Phosphoric Acid minutely pervades most vegetable substances, especially the coverings of seeds.

The Prussic Acid, has been detected in water distilled from bitter almonds, laurel leaves, and peach leaves and blossoms. To the aroma of the latter, its smell has a striking resemblance.

Laurel water has long been known, and used, as a poison. Water distilled from peach leaves, has been used to impart an

agreeable flavour to food. Some, which had been kept for this purpose, being given by mistake to one of my children, was productive of unpleasant symptoms. The consequences might have been much more alarming, had not vomiting mitigated the evil. Some peach-leaf water, prepared by Mr. Wetherill, gave, in my presence, indications of prussic acid.

Instances have been mentioned, where noyeau, a cordial made from the kernels of bitter almonds, has proved poisonous.

The Benzoic Acid is a concrete, volatile acid, existing in Gum Benzoin, or Benjamin, from which its appellation is derived. From this gum the acid may be extricated, by sublimation, or by trituration with lime, digestion with water, and precipitation by muriatic acid.

The presence of Benzoic Acid, characterizes, what is now considered by chemists as a balsam. There are three balsams formed, by its union with particular resins—Gum Benzoin, already mentioned, Styrax, and the Balsam of Tolu.

The word Balsam, has, however, been used heretofore, to designate resins rendered soft or semi-fluid by an essential oil.

An acid, called the Kinic, exists in the Peruvian bark, in union with lime—also in combination with certain alkalies, to which the bark owes its efficacy.

OF FIXED OR FAT OILS.

Oleaginous substances, like olive oil, castor oil, fat, lamp oil, which cannot be distilled unaltered, are called Fixed; while those are called Volatile, which, like the oil or spirit of turpentine, petroleum, cajeput, &c. may, without change, go through the distilling process.

Among the most remarkable of the vegetable oils, are those of the olive, of linseed, poppy-seed, rape-seed. Being procured by expression, they contain mucilage. To the presence of this, the author of the Text Book attributes their liability to become rancid. I have kept a solution of gum arabic for a year, without its acquiring any rancid savour. Rancidity, I suppose to arise from a sort of slow combustion—oil becom-

ing rancid in a heat, that will not change mucilage. Fixed Oils, owe their colour to some extraneous matter, which charcoal removes. They are heavier than alcohol, and lighter than water. They are more or less soluble in ether, especially castor oil. Linseed and olive oils, are soluble in alcohol, which has been deprived of water by pearlash. Castor oil may be dissolved, in any proportion, in alcohol thus strengthened.

The temperatures at which different oils freeze, are very various; and every oil appears to be decomposable, by fusion or congelation, into a less fusible, and more fusible oil.—Hence, in cold weather, a portion of the oil of olives may be seen, separated from the rest, by freezing.

The compound, which they form with the fixed alkalies, is pre-eminently useful, and well known. With soda, they form hard soap—with potash, soft soap: but, the one is made to yield the other, by the addition of chloride of sodium—when the chlorine unites with the potassium, and the sodium with the oxygen and oil, which the potassium abandons.

Water is said to be hard, when it congeals soap. This quality, usually arises from the presence of sulphate of lime, or muriate of soda.

Sulphur is soluble in Fixed Oils, and likewise phosphorus.

An important distinction is to be recollected, existing between what is called drying oil, and those which are otherwise. Linseed oil is rendered drying, by boiling it with the oxides of lead. It does not appear that the rationale of this is satisfactorily given. The author of the Text Book, states it to be, in consequence of the oxides taking up the mucilage. Without this drying property, Fixed Oils could not be used in varnish or in paint.

The Fixed Oils, when distilled, yield a volatile oil, and carburetted hydrogen—carbon remaining in the retort. The volatile oil, thus obtained, is formed during the process. By combustion in the open air, or with oxygen, they are converted into carbonic acid and water. They consist of carbon

and hydrogen, and a small per centage of oxygen. Nitric acid acts with great energy on them, and renders them thicker by imparting oxygen. Chlorine has, indirectly, the same effect. By combining with hydrogen, it increases the proportion of oxygen, in the compound.

The Fixed Oils, especially the drying oils, have the property of inflaming with nitric acid, and entering into combustion with lampblack, or other light carbonaceous matter—also with cotton, wool, flax—and, more lately, inflammation has been discovered to arise, from their mixture with ashes.

I stated above, that every Fixed Oil, appears to be decomposable by heat, or refrigeration, into a less fusible, and a more fusible, portion. It appears, by some experiments made in France, by Chevreul, that vegetable and animal oils, are composed of two different matters—both soluble in hot alcohol, but one of them much less so in cold alcohol. Hence, by the agency of this fluid, they have been separated. The less soluble substance is called Stearin, and the other Elain. Each of these, in the process of saponification, gives rise to an acid, (the margaric, and oleic,) which, combining with the alkali, constitute soap. Another matter is at the same time liberated in small quantity, called the sweet principle, of oils or fat.

OF THE VOLATILE OR ESSENTIAL OILS.

The Volatile Oils, (with the exception of those from the rinds of lemons and oranges, which are procured by expression,) are separated from the vegetable substances, in which they are created, by distillation with water. In consequence of the attraction between the aqueous particles, and those of the Volatile Oils thus procured, the latter pass into the state of vapour, at much lower temperatures than they would otherwise.

The Volatile Oils have usually a penetrating smell, and an acrid taste—a characteristic, in which they are the opposite of the Fixed Oils. When pure, they may be evaporated from any surface on which they may be dropped, leaving no stain.

They unite with alkalies, with great difficulty. They are soluble in alcohol, but not in water. Concentrated nitric acid inflames them. They detonate with chlorates, and ignite in chlorine.

Oils, whether fixed, or volatile, are thickened by exposure to air, in consequence of the absorption of oxygen—according to some chemists. I conceive it more likely, that the oxygen acts by converting hydrogen into water, and thus causing it to evaporate.

Henry suggests, that this absorption of oxygen, accounts for the unhealthfulness of newly painted rooms. At this remark, I am surprised—as the breathing of one person, would take away more oxygen than the paint of any common room.

It seems to me more rational to suppose, that the aëriform matter, which, by its escape, causes the hardening of the paint, carries off a portion of the metallic matter which the paint contains. That there is some volatilization going on, is perceptible, by the smell.

OF CAMPHOR.

Camphor is usually considered, as a concrete volatile oil, which, from its affinity to air, evaporates ere it becomes fluid. It is distinguished, by forming an acid, instead of being inflamed by the action of heated nitric acid. To produce this result, the Camphor is repeatedly distilled, with four times its weight of nitric acid. At a more moderate temperature, this acid dissolves Camphor, forming what was called Oil of Camphor. Muriatic, and other acids, also dissolve this substance. Sulphuric acid and Camphor, reciprocally, decompose each other.

OF ARTIFICIAL CAMPHOR.

When muriatic acid gas, is made to pass through about 100 parts of pure oil of turpentine, surrounded by snow or ice, a quantity of the gas, equal to about one-third of the weight of the turpentine, is absorbed, and the latter is changed into a

soft crystalline mass, from which, by allowing it to drip for some days, about 20 parts of a colourless acid liquor is obtained, charged with many crystals, and 100 parts of a white, granular, crystalline substance, which so much resembles Camphor, in odour, and volatility, that it has received the same appellation. It seems to be a combination of the acid gas, and the volatile oil.

Artificial Camphor is lighter than water. It does not redden litmus. It may be sublimed, but not without partial decomposition. By sublimation through an incandescent tube, it is resolved into the substances of which it was made. It dissolves in alcohol, and is precipitated from it by water, unchanged. Nitric acid disengages chlorine from it.

OF RESINS.

According to Henry, Resins are the inspissated juices of certain plants. I should prefer to say, that Resins exist in the juices of certain plants, in union with essential oils, from which they may be separated, by evaporation or distillation.

Resins cannot be distilled, without decomposition. They are dry, brittle, and inflammable—insoluble in water, but are generally soluble in alcohol, in ether, in essential oils, in alkalies, and in acids. Probably, they may all be combined with fixed oils, (especially Rosin,) but with various degrees of facility.

Copal is not soluble in alcohol, unless camphorated. At a temperature, adequate to its fusion, if Copal be dropped into linseed oil, equally heated, a compound is formed, which, exposed to the air, gradually hardens—and hence its great use as a varnish.

Common Rosin, or Resin, exudes from various pines, especially the Pinus Australis, in union with oil of turpentine, which is distilled from it.

It seems more proper, to use the word *Rosin*, to designate this species—since the formerly synonimous word, Resin, has

been applied to the genus, which Rosin characterizes, in all the most prominent properties.

Strong sulphuric acid decomposes Resins. Nitric acid, by long digestion on them, produces tannin. They are dissolved by acetic acid, and precipitated from it by water.

Resins are of much use for varnishes, when dissolved in turpentine, alcohol, or drying oils.

OF FECULA, OR STARCH.

A substance, of which Starch is a good specimen, and of which the generic name is Fecula, may be obtained from the meal or flour of grain, from the roots of the potatoe, and other vegetables. It is, more or less, a constituent of vegetables in general. When the farinaceous matter, procured from such sources, by rasping or grinding, is washed, the Fecula is suspended, and subsequently deposited.

In the case of wheat, and other grain of a like nature, a fermentation is required, to liberate the Fecula from the other matters entangling it.

Fecula forms a black colour, with a great quantity of iodine —a blue, with less—a violet, with still less—and even a white, when the iodine is at a minimum.

It does not combine with cold water, but forms a viscid fluid with hot water. Alcohol and ether have no action on it. Diluted sulphuric acid, converts it into sugar. It dissolves in cold nitric acid; but, heated with it, yields malic or oxalic acid. A slight torrefaction changes its nature, so that it may be used as a substitute for gum. Triturated with potash, fecula acquires the property of dissolving in cold water. The solution is clouded by acids. Its gelatinous solution by hot water, digested with sub-acetate of lead, forms a combination with the protoxide of that metal.

OF GLUTEN.

The substance left, after washing away the starch from wheat flour, is called Vegetable Gluten. It is to destroy the Gluten, that fermentation is required in starch making.

Gluten is distinguished, by approaching more to the nature of animal matter, than other products of vegetation.—Like animal substances, it yields ammonia by distillation—and of course contains nitrogen. It is to the presence of Gluten in wheat flour, that its pre-eminence in nutritive power is ascribed, by Europeans. By trituration, with alcohol, it is susceptible of forming a kind of varnish.

To the glutinous property of this substance, dough is supposed to owe its rising, during the process of panification, after being mixed with leaven or yeast.

The cellular part of leavened bread, is indebted, for its existence, to Gluten, which, by confining the gaseous matter arising from an incipient fermentation, is inflated into innumerable cavities.

Farinaceous matter, destitute of Gluten, can only be made into heavy cakes, as are those of Indian meal.

One of the principal defects of bread, is sourness, arising from acidity in the yeast. This may be easily removed, by pearlash, or a filtered infusion of clean ashes.

It is alleged by M. Taddei, an Italian chemist, that Gluten, when subjected to alcohol, is separated into two principles—one, soluble in that fluid, which he calls Gliadine—the other, insoluble, which he calls Zimome. Of the presence of Zimome, gum guaiacum is said to be a test—producing, with flour, in which it exists, a fine blue colour—whereas, with starch, or bad flour, guaiacum does not cause this colour.

OF CAOUTCHOUC.

Caoutchouc, or Elastic Gum, is a very singular substance—not only from its extraordinary mechanical properties, but from its insolubility, both in water and alcohol, and remaining untouched even by acids, unless aided by heat. Ether, and the volatile oils, dissolve it slowly. The oil of cajuput, is said to be its best solvent. Turpentine, repeatedly rectified, dissolves it, and forms, with it, an elastic varnish.

Caoutchouc burns with a bright flame, especially in oxygen gas. It exudes, in the fluid state, from certain plants, and

congeals in the form of the mould on which it may be received. After a length of time, it is acted on by alkalies.

It gives ammonia by distillation, and of course contains nitrogen. It becomes warm, when suddenly extended.

OF LIGNIN.

The insoluble, tasteless, inodorous, and tenacious fibres of wood, have been distinguished as a peculiar vegetable matter, and is called Lignin. It is said to yield a trace of ammonia.

OF TANNIN.

There is a principle in vegetables, which has the property of combining with the skins of animals, and converting them into leather. The process, by which this change is effected, is called Tanning—and hence the matter producing it, is called Tan.

Tan, or Tannin, abounds, of course, in the barks used by tanners. It predominates in the nut galls, united to gallic acid—from which, however, there does not appear to be a good means of liberating it. It may be precipitated by muriate of tin, the alkalies, and lime-water, but not pure. It is said to constitute one-half of terra japonica, or catechu—and is still purer in extract of rhatania.

Tannin is formed, artificially, by the action of nitric and sulphuric acids on various matter. The tests of its presence, are muriate of tin, and animal glue. The oxide, or the glue, forms with it an insoluble compound, which precipitates.

OF WAX.

Wax, which is considered, by modern chemists, as a concrete, fixed oil, is a very universal product of the organic world. It covers leaves and fruits, and constitutes, principally, the pollen of flowers. Being thus extensively produced by vegetation, bees-wax was supposed to be collected, not secreted, by the insects, through whose instrumentality we obtain it. But, it has been shown by Huber, that bees, who have access to nothing but sugar, can produce Wax.

There are considerable differences in Wax, as to fusibility, colour, &c. White Wax is produced by a bleaching process, analogous to that by which linen is whitened. It is exposed, in thin lamina, to chlorine, or the air.

Wax is insoluble in water. Boiling alcohol dissolves about one-twentieth of its weight. It retains, on cooling, only $\frac{1}{100}$, and this precipitates, on adding water. Ether, when boiling, takes up one-twentieth. The alkalies convert it into a species of soap. Acids do not act on it—hence it is of great use to defend corks, and other substances, exposed to them. It is the best material for candles, owing to its yielding a tolerably pure carburetted hydrogen, and being less fusible than tallow.

OF THE NEWLY DISCOVERED VEGETABLE ALKALIES.

The discovery of this class of substances, is of the highest importance to mankind. It has enabled the physician, to avail himself of the active principles of some of the most powerful of his remedies, with a certainty, which was before unattainable. The patient, in lieu of being nauseated, and even injured, by doses, of which, the greater part, perhaps the whole, may be inert, if not injurious—has to swallow nothing that can be inefficacious, when judiciously prescribed.

The following are the Vegetable Alkalies, now alleged to exist—in the third edition of Magendie's Formulary :

Morphine, Narcotine, Strychnine, Brucine, Emetine, Cytisine, Cinchonine, Quinine, Esculine, Veratrine, Solanine, Atropine, Daturine, Hyoscyamine, Delphinine, Picrotoxine, Gentianine, Lupuline.

To these words, agreeably to usage, or analogy, in the case of *Morphia*, and *Strychnia*, and other alkalies, we must, in English, affix the termination *a*, to the words, instead of *e*, or *ne*.

But, as English authors do not agree, in their mode of translating these names, and as it were useless to change them, I shall adhere, literally, to the appellations given by the French chemists. At the head of each *alkali*, the French names, and the different names used in England, will be given.

There does not appear any reason for treating, as alkalies, Gentianine and Lupuline. They are not represented, as possessing any one of the alkaline characters.

At the close of the article, *Vegetable Chemistry*, in Ure's Dictionary, *Aconita*, (from Wolfsbane, I presume,) and *Cicuta*, (from the Hemlock,) are mentioned, as alkalies, though not enumerated by Magendie.

These alkalies appear, in almost every instance, to exist in the vegetables to which they belong, in union with some acid.

Thus, Morphine is united with the meconic acid—Cinchonine and Quinine, with the kinic acid—Delphinine, with the malic acid—Veratrine, with the gallic acid. In some instances, the acids have not been specified; but, the method requisite for the analysis, shows that they are present. The salt thus formed, is entangled, sometimes by resinous matter, sometimes by colouring matter, and at others by fatty matter, and, in a few instances, by caoutchouc. Very sparing solubility in water, and comparatively copious solubility in alcohol, are among the most striking attributes of these alkalies. The characteristics, which I have mentioned, must, of necessity, prescribe the methods to be used, in the development of the principles, to which they belong. Potash, soda, ammonia, and lime, or magnesia, are used, to displace the alkali from the acid, naturally in union with it. The alkali thus displaced, from its insolubility in water, precipitates—sometimes with the precipitant, sometimes without it. Strong alcohol is employed, to dissolve the alkali, after precipitation. Previously to this step in the process,—to remove resin, colouring, or fatty matter—water, weak alcohol, or ether, is occasionally used. And in the case of Morphine, when ammonia is added to separate it, and acetic acid to dissolve, animal charcoal is employed to deprive it of colour. A decomposition of the native salts, in which these alkalies are found, is also effected, in some instances, by acetate of lead—when, the acetic acid unites with the alkali, and the oxide with the acid before in union with it, sulphuretted hydrogen being afterwards used, to remove any excess of the metal. Gene-

rally, these alkalies are susceptible of crystallization, and of forming neutral crystallizable salts, with the mineral and vegetable acids.

OF MORPHINE, MORPHINA, OR MORPHIA.

This alkali, is one of the active principles of opium, in which it exists, in union with the meconic acid, and entangled with a great quantity of colouring matter. From the acid, it may be separated, by magnesia, or ammonia. The colouring matter is removed, by washing with cold water, and digestion with weak alcohol. After this, the Morphine is dissolved in boiling hot alcohol, from which it crystallizes, on cooling.

By Dr. Thomson, the Morphine, after having been precipitated by ammonia, in the first instance, is dissolved in acetic acid, and afterwards, is deprived of its colouring matter, by animal charcoal.

Morphine is not soluble in cold, and but slightly soluble in boiling, water.

OF NARCOTINE, NARCOTINA, OR NARCOTIA.

This alkali is obtained from opium, by boiling it, successively, in different portions of ether, each, in weight, double that of the opium. A salt of Narcotine separates, which is purified from resinous matter and caoutchouc, by oil of turpentine, and washing with cold alcohol. It is then dissolved in hot alcohol, and precipitated by ammonia. Subsequent solution in muriatic acid, and precipitation by ammonia, affords the alkali, pure.

Narcotine crystallizes, from its solution in alcohol, in fine needles, or in rhomboidal prisms. It requires 100 parts cold, and 24 parts boiling alcohol, to dissolve it. It is very soluble in hot ether. A grain, given to a dog, produced torpor, without sleep, and death in twenty-four hours.

OF STRYCHNINE, STRYCHNINA, OR STRYCHNIA.

The poisonous principle of the Strychnos Nux Vomica, and Strychnos Ignatia, has been found to be an alkali, which is

called Strychnine. It may be developed, by a process, similar to that used for morphine, above detailed. It was originally obtained, by Pelletier and Caventou, by subjecting the bean of the Strychnos Ignatia, duly rasped, to nitric ether, in a Papin's digester, to remove fatty matter, and subsequent exposure of the residue to alcohol, in which the Strychnine, in union with an acid, dissolves. The alcohol, being evaporated, and the residuum dissolved in water, the addition of potash, caused the alkali to precipitate. It was afterwards washed in cold water, and re-dissolved in alcohol, from which it crystallized, by evaporation.

The colour of Strychnine is white. Its taste is intolerably bitter, leaving a metallic impression in the mouth. It is a terrible poison; very small quantities, producing tetanus, to a fatal extent.

OF BRUCINE, BRUCINA, OR BRUCIA.

This alkali, exists in the bark of the Brucia Antidysenterica. This bark was first subjected to sulphuric ether, and afterwards to alcohol. The alcohol being evaporated, afforded a dry residuum, which was dissolved in water. The solution in water, was saturated with oxalic acid, and evaporated to dryness. The residue was the oxalate of Brucine, disguised by colouring matter, which was removed by alcohol.

The oxalate of Brucine was decomposed by lime, or magnesia, either of which forms an insoluble salt with oxalic acid; while the Brucine is soluble in 500 times its weight of boiling water, or in 850 parts of cold. Hence it may be separated, from the insoluble oxalate, by water.

Brucine crystallizes, in oblique prisms, with parallelograms for their bases. It is less bitter than strychnine, but its taste is more acrid and durable. It melts, when heated a little above 212°, and congeals, on cooling, into a mass resembling wax. It neutralizes acids, affording a distinct class of salts. On animals, its effects are analogous to those of strychnine, but less violent.

OF EMETINE, EMETINA, OR EMETIA.

This alkali is obtained from Ipecacuanha. The roots, duly powdered, are digested in ether: they are then subjected to alcohol—the solution resulting, is evaporated, and the residuum dissolved in water, and macerated upon caustic magnesia, which causes the Emetine to precipitate. This precipitate is washed in cold water, to remove the colouring matter, and afterwards subjected to alcohol, which takes up the Emetine.

The Emetine, again obtained from its solvent by evaporation, must be dissolved in a diluted acid, blanched by animal charcoal, and then precipitated by a salifiable base.

The pure Emetine, obtained by this process, is white, pulverulent, and unalterable by the air—scarcely soluble in water, but easily soluble in ether, or alcohol. Its taste is slightly bitter. It restores the colour of litmus, when reddened by an acid—and is capable of forming crystallizable salts, like other alkalies. It appears to comprise all the emetic properties of the root, from which it is procured.—Two grains, are alleged to be adequate to destroy a large dog.

OF CYTISINE, CYTISINA, OR CYTISIA.

This appears, in the Formulary, classified as an alkali, though no alkaline attribute is ascribed to it.

The seeds of the Cytisus Laburnum, from which Cytisine takes its name, are digested in hot alcohol—the solvent evaporated—the residuum dissolved in water—and acetate of lead added to the solution. The lead is separated by sulphuretted hydrogen, and the remaining fluid filtered and evaporated. The residue is Cytisine. It is uncrystallizable, of a brownish-yellow colour, bitter and nauseous, slightly deliquescent, very soluble in water, and in dilute alcohol, but insoluble in ether.

Cytisine, in its action on the animal system, is somewhat analogous to emetine.

OF CINCHONINE, CINCHONINA, OR CINCHONIA—& QUININE, QUININA, OR QUINIA.

These appellations have been employed, to distinguish the alkalies lately found in Peruvian Bark.

The following are the processes by which they were obtained, by the discoverers, Pelletier and Caventou.

Two parts, by weight, of pale bark, ("Cinchona Gris," or "Cinchona Condamenca,") were subjected, four times, to six parts of hot alcohol. The alcoholic tinctures, were united and distilled, to separate the alcohol: two parts of water being added, towards the close of the distillation, to secure the residuum from injury by the fire. This residuum, received on a filter, employed to separate it from the water, had a red colour, and a resinous appearance. In this state, it was washed with water, weakly alkaline. After many days' washing with alkaline water, this passed the filter, limpid, and without colour. The matter on the filter, was next washed with pure water, and afterwards appeared of a greenish white—very fusible, soluble in alcohol, and gave crystals, which were in the state of the Cinchonine, as discovered by Dr. Gomez, of Lisbon—having some characteristics of a resinous substance. By solution in muriatic acid, very much diluted, a considerable quantity of green fatty matter, was separated. This separation, is imperfectly accomplished, if the acid be strong.

The muriatic solution, was of a golden yellow. Evaporated, it gave crystals, soluble in alcohol, and in water. Its taste was very bitter, and it was precipitated, abundantly, by alkaline solutions—and being slightly heated, and mixed with pure magnesia, it yielded a precipitate: this, after washing it with water, was dissolved in alcohol, producing a very bitter solution, whence crystals of Cinchonine were obtained, by evaporation. By subsequent solution, in the same menstruum, and evaporation, Cinchonine was obtained, in very white, delicate, brilliant, prismatic, needle-shaped crystals.

Cinchonine is scarcely soluble in cold water. It dissolves in the same solvent, when boiling. A thousand parts, by weight, are requisite—and the solution becomes opake, or opalescent, on cooling.

Cinchonine is very bitter—though, from its insolubility, this property is slowly made sensible. Its sulphate, and other soluble salts, are excessively bitter—but, the effect on the taste, differs, from that of a strong decoction of the bark, in not being associated with an astringency, due to another principle.

Cinchonine, by ultimate analysis, is converted into the elements, usually found in vegetables.

The sulphate of Cinchonine, according to Pelletier and Caventou, the discoverers of pure Cinchonine, crystallizes easily in prisms, having four faces, of which the two larger ones terminate in an inclined plane. These crystals are sometimes very delicate, and unite themselves, ordinarily, in bunches. Their taste is excessively bitter. They are soluble in alcohol, but not in ether. Exposed to a heat, a little above boiling, they fuse—and, at a temperature somewhat higher, are decomposed. They consist of about six parts Cinchonine, and one part acid.

Treating the yellow Quinquina, (Cinchona Cordifolia,) by the process, used in developing Cinchonine, Messrs. Pelletier and Caventou were surprised to find a yellowish substance, insusceptible of crystallization. This substance, they were at first led to consider as Cinchonine, disguised by foreign matter. It was, however, finally, ascertained to be a vegetable alkali, analogous to Cinchonine, but not identical with it—and, accordingly, denominated Quinine.

Quinine is uncrystallizable. Entirely deprived of water, by drying, it appears a porous mass of a dirty white. It is very slightly soluble in cold water. Of boiling water, two hundred parts are required for its solution. It is extremely bitter; and retains the water, left in it by the alcohol used as its solvent, with so much obstinacy, as to form a transparent hydrate.

Quinine is very soluble in alcohol—and is much more soluble in sulphuric ether, than Cinchonine, and is less attractive of carbonic acid, when exposed to the air.

Sulphuric acid dissolves Quinine, and forms a salt, which, according to Pelletier and Caventou, crystallizes, in narrow oblong needles, pearly, and slightly flexible, like amianthus.

The analysis of the Red Quinquina, yielded both Cinchonine and Quinine, in much greater quantity, than the Pale or Yellow Bark.

OF ESCULINE.

All that I know concerning this substance, is stated, in the following note to the last edition of Magendie's Formulary, page 78 English translation, where it appears as a quotation from the Journal de Pharmacie of November, 1823.

"M. Carzoneri has lately obtained from the *æsculus hippocastanum*, by a process analogous to the above," (for Cinchonine and Quinine,) "an alkaline principle, to which he has given the name of *esculine:* this principle is supposed to contain all the febrifuge virtues for which the æsculus has been celebrated."

OF VERATRINE, VERATRINA, OR VERATRIA.

This alkali, is obtained from the seeds of the Veratrum Sabadilla—also from the root of the Veratrum Album, or that of the Colchicum Autumnale.

The seeds, partially depurated, by digestion with ether, yielded a coloured tincture to heated alcohol, which deposited some waxy matter, on cooling—and, by evaporation, afforded a residuum, soluble in water, excepting a small portion of extraneous matter. The watery solution, being slowly and partially evaporated, until an orange-coloured precipitate ceased to appear, acetate of lead was added to it: a copious yellow precipitate ensued—and, the liquor, being separated from it by a filter, became almost colourless. This fluid was subjected

to sulphuretted hydrogen, to precipitate any lead which it might contain. The solution, then, with magnesia, gave a precipitate, from which, alcohol took up Veratrine, which was afterwards obtained by evaporation.

Veratrine is white, pulverulent, and inodorous, but nevertheless poisonous, when inhaled, producing violent and dangerous sneezing. Its taste is not bitter, but excessively acrid. In minute quantities, it produces intolerable vomiting, and sickness—and in larger doses, would certainly be fatal.

OF SOLANINE, SOLANINA, OR SOLANIA.

This name has been given to an alkali, lately discovered in a species of the Nightshade, (Solanum Nigrum,) and in the Bitter-sweet, (Solanum Dulcamara.)

The filtrated juice of the berries of the Nightshade, is digested in ammonia: a precipitate, which results, is washed on the filter, and digested in boiling alcohol. After the evaporation of this fluid, Solanine is obtained, in sufficient purity. It is a white, opake, pearly powder, which is inodorous, slightly bitter, and nauseous. Its acid solutions are more bitter. Its salts are uncrystallizable. In cold water, it is insoluble—and hot, dissolves only a small proportion. It restores the colour of litmus, reddened by an acid. It causes vomiting, first—afterwards, sleep.

OF ATROPINE, ATROPINA, OR ATROPIA.

This is an alkali, procured from a decoction of the leaves of the Atropa Belladonna, or Deadly Nightshade. Two pounds of the leaves, were boiled in successive portions of water, which being united, and sulphuric acid added to the whole, the liquid resulting was filtered, and yielded a crystalline precipitate with potash. This precipitate, repeatedly dissolved in acids, and precipitated by alkalies, gave pure Atropine.—Thus obtained, it is snow-white, and quite tasteless. It is,

when recently precipitated, slightly soluble in water. After being dried, it is insoluble in water, ether, or oil of turpentine. In cold alcohol, it is sparingly soluble—but copiously, in the same menstruum, when boiling hot.

Atropine forms salts with acids, which cannot, however, be rendered so neutral, as not to indicate acidity.

In common with several others of the new alkalies, especially aconita, and hyoscyamine, Atropine is poisonous in the extreme. The discoverer, Mr. Brandes, found it impracticable, to prosecute his inquiries respecting them, as far as desirable, from their injurious influence on his health.

OF DATURINE.

This is the appellation, given by Mr. Brandes, to an alkaline principle, which, he alleges, he has extracted from the seeds of the Datura Stramonium. His process, is not described in any of the new publications, which I have seen.

OF HYOSCYAMINE, HYOSCYAMINA, OR HYOSCYMA.

To this alkali, the active qualities of the Hyoscyamus Niger, or Henbane, are due.

It is susceptible of crystallization, and of forming salts with acids.

OF DELPHININE, DELPHININA, OR DELPHIA.

It was in the seeds of the Delphinium Staphisagria, or, Stavesacre, (in which it exists as a mallate,) that this alkali was detected. A decoction of the seeds, which had been cleansed and reduced to a pulp, was filtered: the fluid, which passed the filter, was boiled with magnesia, which liberated the Delphinine. It was then separated from the magnesia, by alcohol—and, from this solvent, by evaporation.

The colour of Delphinine is white—its texture crystalline, while moist: exposure to the air, renders it opake. It is inodorous—but its taste is extremely acrid and bitter. Water

derives from it an acrid taste, though it does not dissolve any appreciable quantity. By combination with acids, it forms neutral salts, which are soluble in water, and very acrid and bitter.

OF PICROTOXINE, PICROTOXINA, OR PICROTOXIA.

From a strong infusion of the Cocculus Indicus, a white crystalline powder was precipitated, by the addition of ammonia in excess. This powder, washed with cold water, and subjected to alcohol, yielded a solution, which, on being evaporated, deposited beautiful silky needles. A similar result was obtained, from an alcoholic infusion of the seeds, by magnesia, which caused a grayish precipitate—from which, alcohol dissolved a matter, crystallizable by evaporation.

In either way obtained, the crystalline precipitate is Picrotoxine: an alkali, which constitutes the poisonous principle of the seeds, from which it is procured.

Picrotoxine is white. Its taste, disgustingly bitter. One hundred parts of boiling water, dissolves only four of Picrotoxine, and one-half of this precipitates, on cooling. Alcohol, of about 810° s. g. dissolves one-third of its weight of this alkali. With sulphuric acid, it formed a salt, in fine silky filaments: also, a neutral compound with nitric acid, which does not appear to have been crystallizable. With muriatic acid, it forms a neutral, insipid, and crystallizable salt. It also forms crystallizable salts, with the phosphoric, acetic, tartaric, and oxalic acids.

Picrotoxine is a most virulent poison.

OF ACONITINE, ACONITINA, OR ACONITA.

From the Aconitum Napellus, or Wolfsbane, the active principle has been extracted. It has received the name of Aconita, agreeably to the English account of it, which is the only one I have seen. It is, of course, liable to be called Aconitine, or Aconitina. It is supposed to be an alkali.

Since the articles, respecting Morphine and Narcotine, went to press, it has occurred to me, that it may be proper to mention a method, which has been employed, to separate Narcotine from Opium—and thus to produce a laudanum, devoid of the unpleasant properties of this alkali.

It has been alleged, that, as Narcotine is very soluble in ether—digestion of the residuum, of an evaporated infusion of opium, repeatedly, in successive portions of that solvent, will remove the Narcotine, and leave the Morphine.

OF GENTIANIN, LUPULIN, CATHARTIN, PIPERIN, & NICOTIN.

OF GENTIANIN.

This name, has been given to a bitter principle, which is obtained from Gentian—by pulverization—digestion in ether—filtration—evaporation—re-solution in alcohol—re-evaporation—solution in *weak* alcohol, to separate oily matter—evaporation of the weak alcoholic tincture—dissolving the residue in water—neutralizing an acid by magnesia, and digesting, in ether, the magnesia, to obtain the Gentianin, which precipitates, in union with it. To effect this last object, thoroughly, the magnesia must be acidulated by oxalic acid.

Gentianin is described as "yellow, inodorous," and as having all the "aromatic bitterness of Gentian." It is very soluble in ether, and alcohol, and sparingly soluble in water. It does not sensibly change the colour of litmus, or restore it when reddened by an acid. It is not poisonous. A solution of it, in alcohol, is represented, as an advantageous substitute for the Elixir of Gentian.

OF LUPULIN.

The Hop, has long been known to possess important properties. By its bitterness, the mawkish sweetness of malt liquors is agreeably qualified—while, at the same time, they

derive from it an aromatic flavour, and an antiseptic quality, without which, they would soon become sour.

Employed in a pillow, or in tincture or infusion, this vegetable has been supposed to act as a gentle anodyne.

A few years ago, Dr. Ives of New York, drew the public attention to a yellow powder, existing in Hops. To this powder, which, according to his observations, is pre-eminently endowed with all their important properties, he gave the name of Lupulin. It has since been found to consist, chiefly, of a resin, a volatile oil, and a bitter principle, soluble in water, alcohol, and ether, to which, severally, it communicates bitterness. It is this bitter principle, which is now called Lupulin, by European chemists.

OF CATHARTIN.

This name has been given to the purgative principle of Senna, by the discoverers, Messrs. Lassaigne and Fenuelle.

A strained decoction of the leaves of this plant, was precipitated, by acetate of lead. The precipitate was washed, diffused through water, and afterwards decomposed by sulphuretted hydrogen. The liquid resulting, was then filtered, and evaporated—the residue subjected to alcohol, and the solution, thus obtained, evaporated. As the mass, remaining, contained potash, it was treated with alcohol and sulphuric acid. The potash, uniting with the acid, was thus rendered insoluble in the alcohol. To remove any excess of sulphuric acid, acetate of lead was added—and sulphuretted hydrogen was employed, to ensure the precipitation of any portion of the lead, which might remain in solution. The liquid, being then filtered, and evaporated, Cathartin remained.

OF PIPERIN.

This name has been assigned to a crystalline matter, obtained from Black Pepper.

Piperin, is described as tasteless, and as possessing no striking qualities.

OF NICOTIN.

Nicotin, is a volatilizable substance, (resembling in many respects an essential oil,) which has been obtained from Tobacco, and appears to be endowed with its most active properties.

The expressed juice of the Tobacco plant, is to be reduced to one-fourth of its bulk, by evaporation, and then poured off, from a gritty deposit which ensues. As a further evaporation, will produce a further deposit, this process is to be repeated, and the fluid decanted, as often as a deposition of gritty matter takes place. When the liquor is so far inspissated, as to prevent any more sediment from separating, the residuum is to be subjected to alcohol, and the resulting solution evaporated. The dry residuum, is again to be exposed to the same solvent, and the matter dissolved, again reduced to dryness. It must next be dissolved in water, and cautiously saturated with potash, to neutralize some malic and acetic acids, which, in this state, are found in it. Distillation, will then cause the Nicotin to pass over into a receiver. By repeatedly re-dissolving the residue in water, and repeatedly re-distilling, the whole of the Nicotin will be procured, in an aqueous solution. This solution is colourless—smells like tobacco—excites violent sneezing—has an acrid taste, and is very poisonous.

Besides the peculiar vegetable principles, of which I have treated, there are others, of a minor degree of importance—as, for instance: Asparagin, from asparagus—Ulmin, from the elm—Inulin, from elecampane—Fungin, from mushrooms—Polycroite, from saffron—Hematin, from logwood—Medulin, from the pith of the sun-flower—Olivile, from the olive tree.

OF CORK.

Cork, is considered as a distinct principle, as its very peculiar mechanical qualities would indicate. It forms, by the action of nitric acid, a peculiar acid, called the Suberic.

OF NAPHTHA, PETROLEUM, BITUMENS, AND MINERAL COAL.

There is a gradation of substances, apparently arising from the wreck of former worlds, from Naphtha, which is one of the most volatile substances, to Anthracite, which is among the most fixed bodies in nature. In the first, carbon and oxygen are at a minimum—in the last, hydrogen and oxygen.

Bitumen is intermediate, between the extremes—being separable, by distillation, into a volatile oil, and coal.

Petroleum is more fluid, lighter, and more inflammable, than Bitumen.

The decomposition of the bituminous matter, in mineral coal, by ignition, yields carburetted hydrogen—as in the Gas-light process.

OF THE VINOUS FERMENTATION.

When certain vegetable infusions, or mixtures of saccharine and farinaceous matter, or the juices of fruits, as those of the apple or grape, are kept at a temperature not above 120° F. nor below 50°, a chemical reaction arises. Water, the presence of which is essential to the process, is decomposed—its oxygen combines with a portion of the carbon of the fermenting matter, and escapes in the form of carbonic acid gas, while the proportion of the hydrogen is increased in the residue, and a new fluid compound is constituted, in which hydrogen predominates. This fluid compound is alcohol, or spirit of wine—to which, the intoxicating power of fermented liquors is due.

OF THE ACTION OF FERMENTS, OR YEAST.

OF ALCOHOL.

By the distillation of fermented liquors, the alcohol in them is separated, as it boils at a lower temperature than water. It still contains, however, more or less of this fluid, and though depurated of it, to a considerable degree, by repeated distillations, the chemical affinity of pearlash, or some other substance attractive of moisture, is requisite, to produce the highest possible degree of strength, in which the specific gravity of alcohol is, to that of water, nearly as 800 to 1000.

The union between alcohol and water, is so energetic, as to cause a rise of temperature, and a diminution of volume, when they are mixed.

Alcohol, by combustion, yields only water and carbonic acid. It is more expansible than water, and boils at 176° F. Its capacity for heat, whether in the liquid, or aëriform state, is much less than that of water. It has never been frozen. It is a powerful solvent, and a most useful agent, in pharmacy, and in the delicate analysis of vegetable and animal matter. I have ascertained, that the addition of one-seventh of oil of turpentine, will render its flame so luminous, as to be a competent substitute for a candle flame.

Alcohol is alleged to consist of equal volumes of olefiant gas, or carburetted hydrogen gas, and aqueous vapour.—When passed through a copper, or porcelain tube, it yields carburetted hydrogen, and aqueous vapour.

EXPERIMENTAL ILLUSTRATIONS.

Mixture of alcohol and water—change of temperature noted.

Apparatus, for demonstrating loss of bulk, exhibited.

Powers of alcohol, as a solvent, contrasted with those of water.

OF SULPHURIC ETHER.

When equal weights of alcohol and sulphuric acid, are mixed and distilled, a fluid, known by the name of Sulphuric Ether, is produced. If the distillation be continued long enough, fumes of sulphurous acid, a peculiar oil, and alcohol containing this oil, together with water and acetic acid, pass over—till at last the mass swells up, so as to render it necessary to terminate the process.

The Ether may be washed in water, in which a small quantity of red lead, or manganese, has been introduced, to remove the sulphurous acid. A little liquid ammonia, diluted with water, purges the fluid, of this acid, instantly. The whole should be subjected to distillation, by means of a water bath, heated to 120°, to separate the Ether—and afterwards raised to a boiling heat, to obtain the alcohol and sweet oil of wine, or Hoffman's anodyne liquor.

Ether is very light—being, in specific gravity to water, nearly as 700 to 1000. It is very volatile. Its power of freezing water, by its evaporation in air; and its ebullition in vacuo, has been illustrated during the first part of this course of instruction. It boils at 98° F. under the pressure of the atmosphere—and, in vacuo, below the freezing point of water.

Ether partially combines with water, but unites with alcohol in any proportion. It freezes at —46° F. It has peculiar and useful powers as a solvent.

Ether is supposed to consist of carburetted hydrogen, and aqueous gas—but, that the proportion of the aqueous gas, is the half of that in alcohol.

OF THE IMPURITY OF THE ETHER, AND THE HOFFMAN'S ANODYNE OF THE SHOPS.

OF NITRIC ETHER.

OF SWEET SPIRIT OF NITRE.

OF MURIATIC ETHER.

OF THE THREE DISTINCT GENERA OF ETHERS.

RATIONALE OF ETHERIFICATION IN GENERAL, AND OF EACH PROCESS IN PARTICULAR.

EXPERIMENTAL ILLUSTRATIONS.

Production, and exhibition, of sulphuric and nitric ethers. Apparatus for nitric ether, contrived by me, exhibited, and ether made by means of it.

OF THE ACETOUS FERMENTATION, AND ITS PRODUCT, THE ACETIC ACID.

ACETOUS FERMENTATION ERRONEOUSLY SUPPOSED TO REQUIRE THE ACCESS OF AIR.

VINOUS, ACETOUS, AND PUTREFACTIVE FERMENTATIONS, ALL DETERMINED, IN A MANNER ANALOGOUS, IN SOME DEGREE, TO THE COMMUNICATION OF DISEASE, BY INFECTION.

ON THE QUESTION, WHETHER THERE MAY NOT BE PECULIAR ANIMALCULES, WHICH GIVE RISE TO THE VINOUS, ACETOUS, AND PUTREFACTIVE FERMENTATIONS—LIKEWISE TO THE EPIDEMICS, ASCRIBED TO MIASMA.

OF PYROLIGNOUS ACID.

OF ACETIC ACID, FROM THE ACETATE OF COPPER, THE ACETATE OF LEAD, OR OTHER ACETATES.

ON THE PROPERTIES OF ACETIC ACID.

ON THE COMPOSITION OF ACETIC ACID.

ON SPIRIT OF MINDERERUS, OR ACETATE OF AMMONIA.

GENERAL CHARACTER OF THE ACETATES.

ON ANIMAL CHEMISTRY.

The observations made, when entering on the subject of Vegetable Chemistry—on the necessity of not pushing analysis to extremes—are equally applicable, in the case of animal matter. Resolving this into its ultimate elements, would only confound substances, differing extremely in their properties. Hydrogen, oxygen, and carbon, are the ultimate elements of the most nutritive, and the most poisonous, animal principles—of the milk of the cow, and the venom of the viper. Our wonder, on observing this elementary similitude in substances, in their nature so discordant, is, however, increased, when we learn, that the carbonization of our own blood, in contact with an alkali, (which is to be obtained from the ashes of bread,) may produce the deadly prussic acid.

When on the subject of Acidity, I suggested, that the occult cause of galvanic polarities, might give rise to corresponding varieties in the quantity, and proportions, of caloric, light, and electricity, in combination with ponderable matter—and thus, create the astonishing diversity, observed in the properties of substances, whose elementary composition is nearly the same.

It may be conjectured, that there are a great many modes, in which the particles of caloric, light, and electricity, may unite with each other—and in which, by subsequent combination with ponderable matter, they may vary its properties. If the light, emitted by a few atoms of tallow, (when burnt in a candle,) be competent to produce the sensation of vision in many hundred millions of eyes—may we not suppose, that

this subtile fluid, and the kindred principles of caloric, and electricity, may have other means of affecting the animal nerves?

Whatever may be the cause, there is an analogy between the effects of an animal gland, and a Voltaic circuit. Within the influence of either, the affinities which prevail, under ordinary circumstances, give place to others, which are productive of new combinations. This demonstrates, that, although all matter may invariably exercise attraction of gravitation—that elective affinity, which gives rise to changes, both within, and without the precincts of vitality, may be adventitious, and dependent on occult and complicated contingencies.

By the digits, by the eight notes in music, or by a few beads in the kaleidoscope, an almost infinite variety of combinations may be produced—each affecting the senses differently. It cannot, then, be surprising, that consequences, no less various, should, in the case of the vegetable and animal creation, arise, from a limited number of elementary principles.

EFFECTS OF IGNITION ON ANIMAL MATTER.

The only difference, between the results of the destructive ignition of animal and vegetable matter, is, that the prevalence of nitrogen, in the former, renders this substance, or its combinations in ammonia or prussic acid, the frequent products of the decomposition of animal substances; and that the charry residuum, of this decomposition, is much more difficult to incinerate.

Like vegetable substances, those of animals, are found divisible into three genera—accordingly as the oxygen is in the same, in a greater, or in a less ratio, to hydrogen, than it is in water.

In the state of sub-phosphate of lime, bones contain a larger proportion of this earth and phosphorus, than exists in any vegetable product; and sulphur is evolved, far more copiously,

during the spontaneous decomposition of flesh, than from vegetable matter, under the same circumstances. Hence the smell of sulphuretted hydrogen, attendant on animal putrefaction.

The most prominent proximate principles of animal matter, distinguishable by that delicate analysis, which has been mentioned as necessary in this department of Chemistry, are..... Fibrin, Gelatine, Albumen, Mucus, Urea, Resin, Sugar, Oils, and Acids.

OF FIBRIN.

Fibrin exists in the chyle, and in the blood, and forms the principal part of muscular flesh. It is, therefore, the most abundant animal substance.

To obtain Fibrin, Thenard advises, that blood, as it flows from a vein, should be beaten with a handful of birch twigs. Each of these, will become loaded with a number of long red filaments, which, by washing in cold water, are whitened and purified.

Fibrin is solid, white, insipid, inodorous—heavier than water—neither acid, nor alkaline—while wet, elastic—when dry, hard and brittle, becoming of a yellowish hue. By distillation, it yields much carbonate of ammonia, and a very bulky shining charcoal, which it is difficult to burn, but which, being burned, leaves a residuum of the phosphates of lime and magnesia, and of the carbonates of lime and soda.

Exposed, in an open vessel, to the action of water, occasionally renewed, Fibrin rots—leaving more or less residue, accordingly as it may have been more or less interlarded by fat. If kept in alcohol for some time, it yields an adipocerous substance, which exists in solution, but precipitates, on adding sufficient water. Ether produces the same results, more speedily. With muriatic acid, it forms an acidulous compound, which may be neutralized, by washing. Its habitudes with sulphuric acid, are similar.

Weak nitric acid, disengages nitrogen gas and oil—and, after about twenty-four hours, converts it into a pulverulent

mass, of a citron-yellow colour, which seems to be a mixture of fat, and fibrin, intimately allied with malic and nitric acid.

Acetic acid, when concentrated, softens and converts Fibrin into a jelly, soluble in hot water.

Cold solutions of the fixed alkalies, dissolve Fibrin, without giving rise to any obvious decomposition. When hot, they liberate ammonia, carbonic and nitric acids.

OF ALBUMEN.

Albumen, though not entering so largely, as fibrin, into the animal organization, is, throughout it, more extensively distributed, than fibrin, or any other proximate element.—United, in various proportions, to water, and minute portions of saline matter, it constitutes the whites of eggs—whence its name, the Serum of the Blood: the liquor of the Pericardium, that produced by dropsy and by blisters. It enters into the composition of the chyle, and, probably, more or less, into all the animal fluids.

Albumen exists, in the solid, and in the fluid state—being converted from the latter, into the former, by heat, or agitation in alcohol. The habitudes of solid Albumen, with acids, or fire, are very similar to those of fibrin. Nevertheless, the alkaline solutions of fibrin, are disturbed by acetic acid—whereas, this acid does not affect alkaline solutions of Albumen.

Solid Albumen, is not soluble in water. Hence, to procure it liquid, recourse must be had to it, in its natural state of fluidity. In this form, it is said to be sufficiently alkaline, to affect tests. Its obvious properties, are universally known, as seen in the whites of eggs. Exposed in the Voltaic circuit, it coagulates about the wire, proceeding from the negative pole.

The phenomenon, of the coagulation of this substance, by heat, is not well explained. As the addition of alkali, causes it to re-dissolve, Dr. Thomson suspects its pristine fluidity to be due to the presence of alkaline matter. But, were his

conjecture correct, cold water ought to coagulate Albumen—and heat could not, unless the alkali were volatile. With most of the acids it combines, producing, generally, insoluble compounds. Hence a very minute quantity, disseminated in water, may be detected, by nitric acid. Phosphoric and acetic acids, do not have this effect. It is precipitated from blood, by acids—and the precipitate re-dissolves, on adding ammonia.

According to Thenard, almost all the metallic salts afford precipitates, with Albumen. These are flocky, and composed of oxide, with some acid, unless in the case of the chlorides and iodides. As these precipitates, are almost destitute of action on the animal system, Albumen has been suggested, as an antidote for metallic poisons.

Corrosive sublimate and Albumen, are, reciprocally, excellent tests for each other; and, from the same cause, the one is an antidote for the other.

Albumen, is coagulated by alcohol: tannin, precipitates it.

Albumen holds, as a constituent, a minute portion of sulphur: hence silver spoons are tarnished by eggs. It is of great use, in clarifying sirups. By mixing with them, while viscid, it envelops any feculent matter, with which it may come in contact—and the union continues, until coagulation ensues, and renders it easy to effect a removal of the compound. It clarifies wine, in like manner—excepting, that the coagulation results, in this case, from the presence of alcohol.

As obtained from blood, or eggs, it forms a very tenacious lute, by admixture with hydrate of lime.

OF GELATINE.

Gelatine, agreeably to the high authority of the French chemist, Thenard, to whom, I am principally indebted, for the substance of my Lectures on Organic Chemistry—never makes a part of the animal humours; yet, the matter, proper for its production, exists in all the soft parts. In this state, it is to be found in the muscles, skins, cartilages, tendons, apo-

neuroses. The membranes, contain a great quantity—the bones, about half their weight.

Gelatine displays no acidity. Nor does it, like albumen, show any trace of an alkali. It is heavier than water—tasteless, colourless, and inodorous; and its ultimate elements, resulting from fiery analysis, are the same as those of albumen, and fibrin. In its habitudes with water, it differs from albumen—being very soluble in boiling water, and difficult to dissolve in cold water. One part, dissolved in one hundred of boiling water, stiffens completely, on cooling—and one part, with one hundred and fifty of boiling water, becomes, as it cools, gelatinous. "This jelly," says Thenard, "sours, liquefies, and putrefies in some days." I have not found this true, in the case of Ichthyocolla, which is the most perfect Gelatine.

Several of the salts and acids, have the property of precipitating Gelatine, but not so unequivocally, as to be good tests of its presence. It is much more soluble in acetic acid, than in water. It is partially precipitated, by alcohol—and totally, by tannin. Alcohol, precipitates it, by taking away the water: tannin, by forming a leather, which is insoluble.

Chlorine, also, produces, with Gelatine, a flocky precipitate.

Gelatine is not acted on, by alcohol, oils, or ether.

By boiling with diluted sulphuric acid, Gelatine is susceptible of conversion into a sugar, which resembles the saccharum of milk, more than cane sugar—especially, in not being susceptible of fermentation.

Gelatine, in the form of Joiners' Glue, is manufactured, for the purposes of the arts, from the clippings of skins, and the ears of animals butchered for the market. These substances, freed from hair and oil, and boiled for a long time, yield a solution of glue, which, when sufficiently concentrated by ebullition, hardens as it cools.

The Gelatine of bones, may be obtained, by the action of water, with heat and pressure. On the phosphate of lime

being removed by muriatic acid, the Gelatine becomes soluble in boiling water.

Ichthyocolla, or isinglass, is obtained from the bladder of a species of sturgeon; and, inferior kinds, from other parts of the same, or of other fishes. It is the finest specimen of Glue, or Gelatine.

The Glue, from bones, is alleged, by Thenard, to be the next best in quality, and is now obtained, extensively, in France.

PORTABLE SOUP. JELLY OF CONFECTIONERS.

OF MUCUS.

The term, Mucus, in an enlarged sense, is applied to the fluid, which lubricates the mouth, œsophagus, stomach, intestines, and other passages of the body.

It differs from albumen, in not being liable to coagulation; nor does it gelatinize, by concentration. Neither tannin, nor corrosive sublimate, affect it. Sub-acetate of lead, renders its solution opake, and afterwards causes a precipitation.

OF UREA, OR THE CRYSTALLIZABLE MATTER OF URINE.

A substance exists, in the Urine of animals, to which, the appellation of Urea has been given.

Urine, is evaporated to the consistence of sirup, by a very delicate management of fire. Nitric acid, is next to be added, by little, and little. The mixture is to be agitated, and placed in an ice bath, to congeal; when a crystalline combination is formed, by the acid and the Urea. The crystals, thus procured, are to be washed with ice-cold water, and cleansed, by allowing them to drip, and pressing them between the folds of blotting paper. The Nitrate of Urea, is afterwards redissolved, and again precipitated, by sub-carbonate of potash.

—The mass, again free, is to be evaporated to dryness, and treated with very pure alcohol, which takes up nothing but Urea, and, by concentration, affords it in pure crystals.

It is, to the presence of this matter, that Urine owes the power of yielding sub-carbonate of ammonia, by distillation.

OF THE COLOURING MATTER OF THE BLOOD, AND OF THE DIFFERENCE BETWEEN IT, AND FIBRIN.

The Colour of the Blood, was, for some time, supposed to be due to oxide of iron, contained in this fluid. Eminent chemists, have lately ascribed it to a principle, analogous to other colouring matters, of the vegetable and animal kingdoms, which do not, in their chemical constitution, show any cause for their various hues. Like them, it may be fixed by mordants, in cloth; and, it has been inferred, that it might be employed as a dye.

It differs from fibrin, only, in its solubility. In water, yielding, when incinerated, about $\frac{1}{200}$ of oxide of iron.

OF ANIMAL RESINS.

Under this head, is placed—the Resin of Bile, Ear-wax, Ambergris, Castor.

OF THE RESIN OF BILE.

By adding one part of muriatic acid, to twenty-two parts of ox bile, a resinous matter is dissolved—and, by subsequent filtration, and evaporation, precipitated. It melts, at about the same heat, as spermaceti. It is soluble in water, as well as in alcohol—and is, of course, deficient of a very essential characteristic of resinous substances.

It is alleged, that this resin is to be considered as the cause of the smell, and, in great measure, of the colour, and taste, of the Bile.

OF CERUMEN, OR EAR-WAX,

According to Henry—" It melts, at a gentle heat—sinks into paper, like an oil—is very combustible—burns with a white smoke, emitting an ammoniacal odour, and leaving little charcoal. With water, it forms a sort of emulsion.—Alcohol, dissolves five-eighths of it, and the remainder has the properties of albumen. The residue of the solution in alcohol, after the evaporation of this solvent, resembles ox bile."

OF AMBERGRIS.

This substance, is found, floating on the sea, within the Tropics. Its origin is not well known, though it is supposed to be given out by the whale. It is not, strictly, a Resin.—Alcohol, extracts from it a peculiar substance, called Ambreine, which is analogous to Cholesterine, a substance obtained from biliary calculi, of which, mention will hereafter be made.

OF CASTOR.

Castor is found, in two small bags, in the inguinal regions of the Beaver. It principally consists of a substance, analogous to the resin of bile.

OF ANIMAL SUGAR.

Sugar is, also, an animal product. Milk whey, evaporated, re-dissolved, clarified by albumen, and evaporated again, yields a species of Sugar, in crystals. It differs from common sugar, in being much less soluble in boiling water, and in not being soluble in alcohol, or fermentable.

The Tartars, are said to ferment their milk, and to make a species of wine from it; yet, in this process, the sugar of milk is alleged to have no participation. The fermentation of milk, is not found to lessen the quantity of the sugar.

Diabetic Sugar, according to Dr. Henry, is more analogous to that of vegetables, than to the saccharum of milk. It approaches to grape sugar.

OF ANIMAL OILS.

Animal Oils, are, generally, less fluid than those of vegetables—being, usually, solid. The whale, nevertheless, and several kinds of fish, yield Oils, at least as fluid, as the oleaginous products of vegetation. Spermaceti, however, (a fatty product of the whale,) is less fusible than tallow—being, in its qualities, between tallow and bees-wax.

OF ADIPOCIRE.

Muscular flesh, under certain circumstances, has been converted into a substance, resembling spermaceti.

This transmutation, was first well observed, on opening a grave, at Paris—in which, a large number of bodies had been buried. They were found, converted into a matter, in its nature intermediate between fat and spermaceti—to which, the name of Adipocire has been given.

It has been alleged, that running water, and, still more, nitric acid, will convert fibrin into Adipocire.

OF SUET—TALLOW—LARD.

Suet—Tallow—Lard—are concrete animal oils, differing in their fusibility. Insoluble, in water—they are slightly acted on, when cold, by alcohol. Hot alcohol dissolves them, and deposites, on cooling, one portion, which is less fusible, but retains another. The first, or least fusible, compound, is called Stearin—the other, Elain. According to Chevreul, the first produces Margaric—the last, Oleic, acid—during the process of saponification.

Elain, may be separated from Stearin, by blotting paper, into which, the latter does not pass. The paper absorbs the Elain, and yields it, upon due pressure.

OF ANIMAL ACIDS.

Among these, are several already described—as, for instance, the Phosphoric, Sulphuric, Muriatic, Carbonic, Benzoic, Acetic, Malic, Oxalic.

Besides these, there are the following :—The Uric, Pyro-Uric, Purpuric, Rosacic, Lactic, Formic, Amniotic, Margaric, Oleic, Sebacic, Cholesteric, Butyric, Delphinic, Prussic.

OF THE URIC ACID.

The Uric, or Lithic Acid, was discovered, by Scheele, in the human calculus. Supposing all calculi to be composed of this acid, he called it Lithic Acid—a name, which has been supplanted by that of Uric Acid, since the concretions of the bladder have been found to consist, occasionally, of other substances. Uric Acid, constitutes the deposition from certain urines, under the form of a yellow powder, which attaches itself so firmly to the recipient, as to be removed with difficulty, even by friction: and all those calculi, or those layers in calculi, which are yellowish, and of which the powder resembles sawdust, are formed of it. The white, in the excrement of birds, consists likewise of the acid in question. It has been found in the excrement of the silk worm, united to ammonia—and in the cantharides. United to soda, it forms anthritic concretions.

It is procured, by treating the sediment of urine, or the yellow urinary calculi, with a solution of potash in excess, and adding muriatic acid. This acid, neutralizing the alkali, and the Uric Acid being almost insoluble in water, it is precipi-

tated in flocks, which, after a time, are changed into brilliant plates. This precipitate, is to be washed, until the washings do not become turbid by nitrate of silver. Gently dried, it becomes a yellowish-white lamellated powder, and does not redden litmus.

Uric Acid, dissolves in nitric acid, and yields, by evaporation, a residuum of a fine red tint. This property, assists in detecting it.

OF PYRO-URIC ACID.

When the uric acid is distilled, per se, another acid is generated, called by the name above mentioned. It rises, in the form of a yellow sublimate, in union with ammonia. This sublimate, being dissolved in water, and acetate of lead added to the solution, a white precipitate ensues, which, after due ablution, is decomposed by sulphuretted hydrogen gas—and, by solution, and evaporation, affords crystals of the Acid, in the form of white needles.

OF PURPURIC ACID.

From a solution of uric acid, in nitric acid, on the addition of ammonia, dark red crystals are separated, which are to be dissolved in a solution of potass, and subjected to heat, until the redness disappears. The solution, being then decomposed by diluted sulphuric acid, Purpuric Acid is precipitated, in a fine yellowish, or cream-coloured powder, without taste or smell—and which, when seen by a magnifier, exhibits a pearly lustre. Though it does not redden litmus, it is capable of saturating alkalies; and, when in aqueous solution with them, produces a beautiful deep carmine, or rose-red colour.

OF ROSACIC ACID.

The lateritious sediment, obtained from the urine of diseased persons, contains, according to the best authority, an acid,

called Rosacic, from its rosy colour. It differs from the uric acid—in being very soluble in hot water—in having little tendency to crystallize—and, in precipitating muriate of gold, of a violet colour.

OF ERYTHRIC ACID.

If pure uric acid, be dissolved in nitric acid, in excess—the solution evaporated, and left in a cool situation—crystals are obtained, of a substance, supposed to be an acid, and called by the above mentioned name.

OF LACTIC ACID.

Lactic Acid, is that produced in milk, when it sours. It acts with so much energy, on iron and zinc, as to cause the evolution of hydrogen gas.

It is procured by saturating sour whey with chalk, or lime-water, and afterwards precipitating the lime, by oxalic acid—evaporating to a sirup—solution in alcohol—and evaporating again.

OF SACCHOLACTIC, SACLACTIC, OR MUCIC, ACID.

The sugar of milk, subjected to nitric acid, (as in the process for obtaining oxalic acid,) yields a peculiar acid, called by the names above mentioned.

OF FORMIC ACID.

The Formic Acid, is obtained by crushing Ants. It appears to exist in them naturally. It was alleged, by Fourcroy and Vauquelin, to be acetic acid, disguised by impurities;—but, it appears, from the experiments of Berzelius, to approximate, in its composition, to the oxalic, more nearly, than to the acetic.

OF AMNIOTIC ACID.

The Amniotic Acid, is a peculiar acid, found only in the liquor of the amnios of the Cow.

OF CHOLESTERIC ACID.

There is, in the biliary calculi of men, a peculiar fat matter, which M. Chevreul calls Cholesterine. This, when treated with nitric acid, produces a peculiar acid, called Cholesteric Acid.

OF MARGARIC AND OLEIC ACIDS.

These acids, are said to be produced, during the process of saponification—also to be found in the fat of dead bodies.

OF PRUSSIC, OR, HYDROCYANIC ACID.

When potash is ignited, in contact with animal matter, cy anogen is formed, by the union of carbon and nitrogen. The new compound, enters into combination with the potassium, (of the potash) with which, it constitutes a cyanide, or cyanuret. The cyanide, thus created, being dissolved, and sulphate of iron added, a complicated reaction ensues. The cyanogen, gives up the potassium to the oxygen of the water and sulphuric acid—while the hydrogen of the water, and the oxide of iron, form with it a prussiate, or hydrocyanate, of iron. At the same time, a cyanide of iron is produced, and unites with the prussiate of iron—making, what has been called, a ferro-cyanate, or ferro-prussiate.

Boiled with potash, the cyanide of iron, and hydrocyanic acid, unites with the alkali—forming a ferro-prussiate, or ferro-cyanate, of potash.

Boiled with red precipitate, or red oxide of mercury, Prussian blue cedes its cyanogen to the mercury—forming a cyanide, analogous to the chlorides of the same metal.

Cyanide of mercury, heated, yields cyanogen—a gas, composed of nitrogen and carbon. Distilled with muriatic acid, it combines with the hydrogen of this acid, and forms Prussic, or Hydrocyanic Acid, which passes over, while the chlorine forms a chloride with the metal, and remains in the retort.

To make Prussic Acid, of a strength sufficient for medicine, the muriatic acid should be diluted with six times its weight of water, and added to an equal weight of the cyanide —after which, six pints of the dilute Prussic Acid, may be drawn over, by distillation.

It may be more easily obtained, by exposing, to a current of sulphuretted hydrogen, a solution, consisting of 60 grains of cyanide of mercury, for every ounce of water. The hydrogen unites with cyanogen, while the sulphur precipitates with the metal. Any excess of the sulphuretted hydrogen, is easily removed by the carbonate of lead.

The Acid may be procured, in its most concentrated form, by exposing the cyanide, in crystals, to sulphuretted hydrogen, and employing a tube and receiver, surrounded by salt and snow, to condense the vapour evolved.

EXPERIMENTAL ILLUSTRATIONS.

Evolution of Prussic, or Hydrocyanic Acid, in the concentrated form, and in a state of dilution.

OF THE PROPERTIES OF HYDROCYANIC ACID.

Hydrocyanic Acid, is far more volatile than ether, as it boils at 70° F. and evaporates so rapidly, thàt one portion becomes frozen, by the loss of the caloric which the other absorbs, in passing into the aëriform state. Its specific gravity is .7058, being nearly the same as that of sulphuric ether.—A drop, allowed to fall on the eye, or on the tongue, of a small animal, kills it instantly. The consequences, are equally deleterious, when the fumes are applied to the nose.

OF CHLOROCYANIC ACID.

OF SULPHOCYANIC ACID.

OF THE BLOOD.

From the proximate elements of animal matter, we proceed to the more complex substances of which they are composed. Among these, Blood is, of all others, the most important.

It consists of water, albumen, fibrin, colouring matter—of a small quantity of fatty matter—of minute portions of the muriates of potash and soda, sub-phosphate of soda, sub-carbonate of lime and magnesia, oxide of iron, and, according to Berzelius, of some lactate of soda, united to some animal matter. Its obvious properties, are well known. Within the sphere of vitality, it is always fluid. Its colour is bright red in the arteries, and dark red in the veins. Its taste is saltish, and its smell faint. In gravity, it exceeds water.

Left to itself, it soon separates into the serum, and crassamentum or clot; the proportion of the latter being greater, as the animal is better fed, or more healthful. Heat was supposed to be extricated, during the coagulation; but, it has been shown, of late, to be scarcely appreciable by the thermometer. The serum, like other albumen, may be coagulated by heat, and then yields a liquor, called the serosity, which Dr. Brande supposes to be albumen, in combination with a large portion of alkali, as it yields albumen, when placed between the poles of the Voltaic series.

Potash and soda, diminish the tendency of the Blood to coagulate—while acids hasten it. The alkalies act, by rendering the fibrin more soluble—the acids, by coagulating the albumen.

Almost all metallic salts, excepting those of the alkalies and earths, produce a precipitation in Blood, in consequence of an affinity between albumen and the oxides, and, partially, the acids. Alcohol, by taking hold of the water, precipitates all the other matter.

It has been stated, that the Blood in the arteries is of a much brighter red, than that in the veins. This difference, is evidently consequent to its exposure to atmospheric air, during its circulation through the lungs.

Amidst the aggregate of all that has been said, and written, on this subject, Chemistry informs us, that the oxygen of the breath is partially converted into carbonic acid, during respiration—and that it is inconceivable, that caloric should not be given out, during the carbonization of oxygen gas, in this, as in all other cases. Our knowledge of the modes, in which caloric appears and disappears, is, as yet, too imperfect, to justify a conclusion, that this principle is not yielded to the Blood; because, we cannot detect an excess of sensible heat, in the organs of respiration.

At the same time, it is very consistent with the prevalent chemical doctrines, to suppose animal heat engendered and supported by that change of capacity, which so often causes a rise of temperature to accompany chemical reaction.

There is an obvious analogy, betwen the process by which heat is produced by germination and by fermentation, and that, by which it may arise in animals, independently of respiration.

OF THE SALIVA.

It is the fluid which is secreted, in animals, from the blood into the mouth—especially during mastication, or on the sight of food, while hungry.

To procure Saliva, Thenard advises us, to place a famished dog (his mouth muzzled or gagged,) near a piece of smoking roast meat. From the fauces of the animal, thus cruelly tantalized, the fluid in question, flows copiously.

According to Berzelius, Saliva contains only 7 parts in 1000, of other matter than water. The most important observations respecting it, are those of Dr. Brande, by means of the Voltaic pile—which, he found to separate from it, albumen and alkali.

Saliva contains the alkaline muriates, lactate of soda, mucus, and some other animal matter.

OF THE GASTRIC JUICE.

The Gastric Juice is a transparent liquor, having a somewhat bitter taste, and neither acid nor alkaline. It appears to contain albumen, gelatine, and mucus. In herbivorous animals, phosphoric acid is found—but not in that of carnivorous animals.

ON THE QUESTION, WHETHER THE GASTRIC JUICE HAS THE POWERS OF A CHEMICAL SOLVENT.

OF THE PANCREATIC JUICE.

The Pancreatic Juice is analogous to the saliva.

OF BILE.

The Bile, of different animals, possesses different characteristics—both as to obvious properties, and chemical habitudes. Human Bile, contains a peculiar yellow matter—albumen—a sort of resin—soda—phosphate of soda—muriates of potash and soda—phosphate of lime—perhaps magnesia—and some traces of iron.

It is in the human biliary calculi, that Chevreul has discovered the fat substance, which he calls Cholesterine—and which differs from adipocire, spermaceti, or fat, in not being susceptible of saponification.

OF MILK.

Milk, needs no description. Its density, and qualities, vary, not only in different animals, but at different times in the same animals, according to health, or food. It spontaneously separates, into butter, curd, and whey. This separation is hastened by the rennet—the effect of which, it is not easy to explain. As it is not prevented by the presence of an alkali, it cannot be ascribed to acidity.

Milk is composed of cheesy and buttery matter, of sugar of milk, of different salts, especially phosphates, and a little acid. The cheesy and buttery matter, are only suspended in the Milk—whence its opacity; and, when evaporated, form a pellicle on its surface. By distillation, it yields water, slightly contaminated with milk. If heated daily, it does not spoil for a long time. It is extremely coagulable, by acids. Alcohol, in considerable quantity, coagulates Milk, by taking hold of the water; and the same result follows, from the admixture of other neutral substances attractive of water. Alkalies have the opposite effect, as they dissolve the cheese, which consists of fibrin and albumen.

Whey, as I have stated, contains sugar of Milk; and, besides this, some other animal matter, with phosphates and muriates.

The Milk of Women, contains less caseous matter, and more sugar, than Cows' Milk. It yields more cream, but not of a kind convertible into butter.

OF CHEESE.

OF CASEOUS OXIDE, AND CASEOUS ACID.

OF CHYLE, AND ITS INTERMEDIATE CHARACTER BETWEEN MILK AND BLOOD.

Chyle, is of a nature intermediate between that of milk and blood. Though susceptible, like the latter, of coagulation, the coagulum is more like cheese than fibrin.

Chyle contains albumen, a little fibrin, some saline matter, and a trace of oil and sugar.

OF THE MUCUS OF THE NOSE.

The Mucus of the Nose, besides water, which constitutes $\frac{93}{100}$ of it, consists of mucus proper, muriate of potash, muriate of soda, lactate of soda, albumen, and other animal matter.

OF TEARS.—OF THE AQUEOUS AND VITREOUS HUMOURS OF THE EYE.

Tears, are similar to the mucus of the nose, but more fluid.

The Aqueous, and Vitreous Humours, consist of water, albumen, and the usual neutral salts.

OF LYMPH.

Lymph, seems to consist, principally, of albumen, rendered soluble by an alkali. It contains some saline matter, especially muriate of soda.

OF SYNOVIA.

Synovia, contains about 80 parts water, $4\frac{1}{2}$ parts albumen, and between 11 and 12 parts of fibrous matter—besides, some carbonate of soda, muriate of soda, and phosphate of lime.

OF URINE.

Urine is a very complicated fluid—being obviously secreted for the purpose of carrying off any excess of saline or other matter, received into, or formed in, the animal system.

Besides water, Urine contains acids, salts, alkalies, earths, gelatine, albumen, urea, sulphur.

The Acids, are the phosphoric, uric, fluoric, lactic, sulphuric, muriatic.

The Alkalies, are soda, potash, ammonia.

The Earths, are lime, magnesia, silica.

Of course, the Acids and Earths are, more or less, neutralized by each other—forming phosphates, urates, fluates, lactates, &c.

That there is an excess of acid in Urine, is evident, from its injuring colours. To the same excess of acid, is due the solution in it, of the otherwise insoluble earthy phosphates.

OF THE URINE OF HERBIVEROUS ANIMALS.

OF URINARY CALCULI.

From the consideration of Urine, we pass to that of the Concretions, formed from it, in the bladder. These are, according to Henry:—

I.—Calculi which are chiefly composed of uric acid, or urate of ammonia:

II.—Calculi principally composed of the ammoniaco-magnesian phosphate:

III.—Calculi consisting, for the most part, of phosphate of lime:

IV.—Calculi containing principally carbonate of lime:

V.—Calculi which derive their characteristic property from oxalate of lime; and

VI.—Calculi composed of the substance discovered by Dr. Wollaston, and called by him *cystic oxide.*

To these may be added, Calculi, containing two or more of the ingredients, above mentioned, in a state of admixture—and those in which they form alternate layers, or concentric strata.

Dr. Marcet informs us, that when the uric acid predominates in a calculus—a fragment, no larger than a pin's head, being held in the blowpipe flame, by a slender pair of platina tongs, blackens—emits a smoke, having a strong and characteristic odour—is gradually consumed—and leaves a minute quantity of white ash, which is usually alkaline.

Another mode of recognizing this calculus, is, to subject a small portion, in a watch glass, to a few drops of caustic potash, over a lamp. The uric acid is immediately dissolved, leaving the other ingredients untouched. From the solution thus formed, almost any acid (even carbonic acid) will cause a white precipitate of pure uric acid.

Lastly—if a minute portion of calculus, consisting of uric acid in the smallest proportion, be exposed to a drop of nitric acid, and heated to dryness, the residuum will display a beautiful pink, or carmine colour.

When phosphate of lime, predominates in a fragment of calculus, it first blackens, but soon after becomes perfectly white, and is very difficult of fusion before the blowpipe.—Calculi of this kind, are readily dissolved by dilute muriatic acid ; and, when the acid is not in great excess, may be precipitated by oxalate of ammonia.

If a calculus, consisting principally of ammoniaco-magnesian phosphate, be subjected to a gentle heat, or moistened with caustic potash, an ammoniacal odour will be perceptible.

There is a species of calculus, which, when exposed to the blowpipe flame, bubbles up, and melts easily into globules, usually pearly, but sometimes transparent. This species, is called the Fusible Calculus. It is, principally, a mixture of phosphate of lime, and ammoniaco-magnesian phosphate. It is readily soluble in dilute muriatic acid—from which, the lime may be precipitated, by the addition of oxalic acid ; and by adding ammonia, a precipitation ensues, of ammoniaco-magnesian phosphate.

The calculus, in which oxalate of lime predominates, is sometines called the Mulberry Calculus, from its resemblance to a mulberry. The heat of a spirit lamp, is generally adequate to destroy the acid, and to develop quick lime in this calculus, which may of course be detected by the alkaline tests.

Cystic oxide is recognized, *chemically*, by its great solubility in acids and alkalies.

OF BONES.

The Bones of Animals, consist of animal matter, indurated by phosphate of lime, with some carbonate of lime, still less phosphate of magnesia and fluate of lime, soda, and muriate of soda. The animal matter, is alleged to be gelatine, and albumen.

OF THE BRAIN.

The Brain, is said to contain, in 10,000 parts :

Water, - - - - - - - -	8000
White fatty matter, - - - - - -	453
Red fatty matter, - - - - - -	70
Albumen, - - - - - - - -	700
Osmazome, a substance to which meat gravy is supposed to owe its savour, - - - -	112
Phosphorus, - - - - - - -	150
Acids, salts, and sulphur, - - - - -	515
	10,000

Such, is the best account, which, it has pleased God, to enable the Brain of Man to give, of its own chemical constitution.

It is to be regretted, that, of all studies, to which the human mind has been directed, self-analysis, whether moral or physical, seems the most beyond its powers.

CONCLUDING ADDRESS, ON THE SUBJECT OF VEGETABLE AND ANIMAL CHEMISTRY.

Of Vegetable and Animal Chemistry, I must here take leave. Intrinsically, it appears little more than a detail of facts.—It is only from the splendid discoveries, which have been made in the Chemistry of Inorganic Matter, that we can hope for any theoretic elucidation of the properties of organic products, or of the means by which vitality creates, from sources so limited, consequences, so very extensively diversified, and so susceptible of further diversification.

From the multiplicity of analyses, of which the results are so nearly alike, as to baffle the efforts of the adept, to remember them duly—it were utterly impracticable, to impart a

knowledge of the minutiæ of Vegetable and Animal Chemistry, during a course of instruction limited to four months. It is, however, consolatory to reflect, that it is that branch of the Science, in which, it is most easy for gentlemen of the medical profession to acquire spontaneous improvement—as the subjects are within their reach, and the implements and agents for investigation, are very simple, and may be obtained, comparatively, with little exertion and expense.

LECTURES

ON

ELECTRICITY & GALVANISM.

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PRINTED FOR THE USE OF HIS PUPILS.

ON ELECTRICITY.

HISTORY OF ELECTRICITY.

An attractive power is acquired by resins, sulphur, glass, and a variety of other substances, when rubbed; and if the masses, thus excited, be sufficiently large, the phenomena of light, of mechanical concussion, and ignition, may result—and even a feeble imitation of thunder and lightning.

As it was in Amber, in Greek called *Electron*, that the attractive power, arising from friction, was first observed; the principle to which it was ascribed, was called Electricity—and all substances, in which it could be produced, Electrics.

We are informed, that Thales, of Miletus, who flourished six hundred years before Christ, was so much struck with this effect of the friction of amber, as to imagine that it might be endowed with animation. Subsequently, it was ascertained, that the attractive power, which had been observed in amber, when subjected to friction, might be produced, by the same means, in other resinous substances; and, in the tourmaline, or lyncurium, as it was then called, by exposure to heat.

No further progress was effected, in Electrical knowledge, until the seventeenth century of the Christian era, when, after considerable additions had been made to the catalogue of Electrics, by Gilbert, and Boyle—Otho Guericke discovered, that light, and sound, might be consequences of the electric ex-

citement. His observations were made, by means of a globe of sulphur, cast in a glass vessel of the same shape, which was fractured to extricate the casting. Little was it suspected, by the ingenious operator, that the vessel thus broken, would have answered better, for the purpose in view, than the sulphur globe, in the moulding of which it was sacrificed.

The discovery of the usefulness of glass, as a mean of producing Electricity, appears to have been made by Hawkesbee, who wrote in 1709. To Grey, who followed Hawkesbee, we owe the remark, that the electrical excitement of glass, and other electrics, was communicable to other bodies, when insulated, not only by direct contact, but by wires or threads of great length; and, by this Electrician, in conjunction with another named Wheeler, it was first observed, that this property, of conducting the electric virtue, while belonging to thread, did not belong to silk; also, that by the class of bodies, in which Electricity can be excited, it cannot be conducted—whilst in those by which it may be conducted, it cannot be excited. Thus were two classes of bodies distinguished; electrics, or non-conductors—and non-electrics, or conductors.

It was ascertained, however, that a conductor, if supported by a non-conductor, might receive the electric virtue from an excited electric. A conductor, so supported, was said to be *insulated.*

Du Faye, soon after, ascertained the important truth, that there are two kinds of electrical excitement. One of these, being observed in glass, was called vitreous—and the other, resinous, because observed in resins. By the communication of either species of excitement, light bodies were made to separate from each other; but, the bodies excited by means of resins, were attracted by such as were excited by means of glass; and when these opposite excitements were made, in due proportion, in different insulated conductors—on bringing the conductors together, a neutralization, and of course an apparent annihilation, of the electricity in both, was the consequence.

The means of collecting the electric fluid, were, soon after, much improved in Germany—where many globes of glass were whirled at once, and their joint product emitted, at the same time, in sparks sufficient to kill birds, and ignite spirits, or other inflammable matter.

In the year 1746, the Leyden Phial was invented. Cuneus, and Mushenbrœck, attempting to charge, with electricity, the water contained in a phial, a shock was experienced by Cuneus, who happened to touch the conductor with one hand, while grasping the phial with the other.

This phenomenon, was soon after explained by Franklin.—He had ascertained, that whenever either kind of electricity is communicated to one body, the other kind will be communicated to another body—provided both the bodies are insulated. When a glass is rubbed by the hand, it takes electricity from the hand, and the person to whom it belongs. If, standing on a non-conductor, the person will be electrified, at the same time that the glass which he rubs may, by contact, excite another body; but, then, the electricity of the person who rubs the tube, and that of the body to which he presents the tube, are of opposite kinds. The former being the resinous, the latter the vitreous electricity, of Du Faye. A stick of resin would cause the opposite result, producing vitreous electricity in the person rubbing it—and resinous, in a body touching the resin.

These phenomena, were thus accounted for, by Franklin.—Some bodies, (glass for instance) by friction, acquire additional power to hold the electric fluid—and hence draw it from the conducting body rubbing them, and give up the excess to any adjoining conductor, when the friction ceases.—Resins, on the other hand, have their capacity for the electric fluid lessened, by rubbing—and hence, while subjected to this process, give it out to the rubber, and afterwards draw on any adjoining body, to supply their deficiency. Glass, and resin, therefore, produce both kinds of electricity, which are merely the result of an accumulation, or deficiency, in an insulated body, of a fluid which pervades all nature. A con-

ductor, charged in either way, will produce an electrical current, when presented to other bodies in connexion with the earth. In the one case, electricity will flow into the conductor; in the other case, it will flow out of it.

Franklin, also, discovered, that when an electrical stream is directed into a phial, situated like that of Cuneus, there is, at the same time, a stream proceeding from the outside; so that, in proportion as one surface gains, the other loses—and, accordingly, in a charged phial, one surface will be found vitreously, or redundantly, excited—the other, resinously, or deficiently; and a light body, after touching either surface, will be repelled by it, and attracted by the other.

He inferred, that there was only one electric fluid—to different states of which, the names of vitreous, and resinous, electricity, had been applied erroneously. The latter he called negative, the former positive, electricity.

Franklin, afterwards, identified lightning with electricity—by drawing this fluid from the clouds, by means of a kite; availing himself of a contrivance, which had previously been appropriated to juvenile recreation, to make a discovery, which will ever be considered as among the most sublime, and useful attainments, of human genius.

ELECTRICITY,

EXPERIMENTALLY ILLUSTRATED.

ORDER TO BE PURSUED, IN THE EXPERIMENTAL ILLUSTRATION OF ELECTRICITY.

Of the ordinary means of producing Electricity.—Communication of Electricity.—Different kinds of Electricity.—Means of accumulating Electricity.—Means of detecting Electricity.—Effects of Electricity.—Additional means of producing Electricity.—Theoretic explanation of Electrical Phenomena.—On the question, whether there be two Electric Fluids, or one only.—Means of Electrifying Patients; either with sparks, or by shocks.

OF THE MEANS OF PRODUCING ELECTRICITY.

It has been stated, in the preceding Lecture, that an attractive power is acquired, by resins, sulphur, glass, and a variety of other substances, when rubbed :—also, that bodies, susceptible of this species of excitement, are called Electrics—and the principle, on which it is supposed to be dependent, is called Electricity.

EXPERIMENTAL ILLUSTRATIONS.

Friction of amber, glass, resin, sulphur. Large glass tubes rubbed—also, cylinders of sulphur and of resin. Thin metallic leaves attracted, at a considerable distance, either by the glass, the sulphur, or the resin.

Electrical Machine exhibited, and explained.—Attraction of pith balls.

OF THE COMMUNICATION OF ELECTRICITY.

The electric virtue, cannot pass from one part of an electric which is excited, to another, without extraneous aid; nor can it pass off, from one electric, through any other.—Hence these substances are called non-conductors. Through metals, on the other hand, it escapes instantaneously. It passes with ease through a flaxen or hempen thread, but not through silk. Water, it pervades with great facility—or any thing which contains moisture.

Substances, which are thus capable of transmitting electricity, are called conductors—and are divided into perfect, and imperfect, conductors. The metals, are the only perfect conductors. All other conductors are imperfect; and, at the head of this class is charcoal, as being the best conductor of electricity, next to metals.

EXPERIMENTAL PROOFS, THAT ELECTRICITY DOES NOT PASS FROM ONE PART OF AN ELECTRIC TO ANOTHER, THROUGH, OR BY MEANS OF, THE ELECTRIC.

One part of a cylinder of sulphur, or of glass, being excited by friction, so as to attract light bodies—another part, not being rubbed, is not found to attract them.

Glass globe, or cylinder, on a pivot, being excited on one side by a wire (No. 1) proceeding from the Electrical Machine—the side, thus excited, is attracted by a wire (No. 2) on the other side, communicating with the floor, to which, as it approaches, it gives up its electricity. Meanwhile, other portions of the globe becoming excited by wire No. 1, are attracted by wire No. 2, and thus the globe revolves, in order to discharge its electricity.

A conducting mass, being placed on the pivots, in lieu of the electric, no revolution takes place. The

electricity passes, in sparks, from one wire to the other, through the conductor, instead of causing it to revolve.

A number of glass balls placed on a plate of glass, surrounded by a brass ring. On the plate are strips of tin foil, partially distributed, and connected by a chain with the floor. The ring, being electrified by a machine, the balls are attracted, and charged by it, in the parts which touch it—these parts are then attracted by the foil on the plate, and, giving up their charge, go back to the ring, and then return to the foil. Globular conductors, being substituted for the glass balls—on the balls being moistened, no movements can be produced. In this case, the electricity being equally distributed all over the balls, no one part is more attracted than another, either by the ring, or the tin foil.

EXPERIMENTAL PROOFS, THAT METALS, CHARCOAL, MOISTURE, FLAX, OR HEMP, ARE CONDUCTORS OF ELECTRICITY—AND THAT SULPHUR, RESINS, GLASS, SILK, AND WOOL, ARE NON-CONDUCTORS.

The Electrical Machine, being in operation, so as to emit sparks, or to act upon pith balls, or other light bodies—those electrical phenomena cease, when the conductor, which is the immediate cause of them, is touched with a rod of metal, or by a piece of charcoal, communicating with the earth---and they are lessened, when one end of a hempen or flaxen string is attached to the conductor, while the other end is held in the hand, or lies upon the floor.

The conductor being excited, as above described, the phenomena do not cease. in consequence of the contact of a glass rod, or of cylinders of sulphur or resin; nor are they diminished, by an attachment

of woollen or silken strings, as in the case of those of flax or hemp. The glass rod, or the woollen or silken strings, being moistened, the electricity is carried off by them from the conductor; and moistening or drying the strings of hemp or flax, is found to heighten or lower their conducting power. The electricity escapes from the conductor, with ease, through a tube filled with water.

OF THE DIFFERENT KINDS OF ELECTRICITY.

It may be learned, from my brief account of the rise and progress of Electricity, (" History of Electricity," page 4) that the electrical excitement which may be produced in glass, by friction, differs from that which may be produced in resin, or sulphur: that light masses, as paper, or pith balls, separate from each other, when either excitement has been solely imparted to them—but if one body receives the resinous, the other the vitreous excitement, an attraction between them will ensue. Both excitements, in due proportion, neutralize each other. Also—whenever either excitement is produced, in one body, the other will arise in some other, if both bodies be supported on non-conductors, so as to prevent the escape of the electricity, as soon as generated. Hence if a person, standing on a glass stool, rub a tube of the same material, he will be found resinously electrified—while any body, to which the glass may be presented, will be vitreously electrified. A stick of resin, being substituted for the glass, and rubbed in like manner, and under the same circumstances, the same phenomena will appear, in a different order:—the person rubbing the resin, will be vitreously excited—while the excitement of the body, to which it is presented, will be resinous.

In like manner, when the cylinder of the Electrical Machine is put into motion, the insulated cushion which rubs it, acquires the resinous excitement—while the prime conductor

becomes excited vitreously. If a globe of sulphur, or resin, were substituted, the cushion would receive the vitreous excitement—while the conductor would be excited resinously.

EXPERIMENTAL ILLUSTRATIONS.

Gold-leaf Electrometer exhibited, and explained. The leaves diverge, on the approach either of excited sulphur or glass; but when both are approximated to it, at once, the leaves will display no divergency.

Electrical Machine produced----each conductor being furnished with a Quadrant Electrometer. As the cylinder is turned, the pith ball of each Electrometer rises. As often as a spark is taken from either conductor, the pith ball of the Electrometer on it, falls; and when a metallic wire is made to touch both conductors, simultaneously, neither of the pith balls indicates any excitement. Sparks taken from a metallic knob communicating with the positive conductor, compared with the sparks emitted from the same knob, when communicating with the negative conductor.

OF THE MEANS OF ACCUMULATING ELECTRICITY.

When, as in the case of the electric cylinder machine, insulated conductors are electrified by an electric surface, successively rubbed by one conductor, and brought near another, it has been shown, that whatever electricity is gained by one, is lost by the other; so that the whole quantity in both, remains the same as before the excitement was induced.

It has also been shown, that the electric fluid does not pass through electrics, or from one part of an electric to another.

I shall now proceed to demonstrate, that if an electric, sufficiently thin and strong, (as a pane of glass for instance,) be charged on either side with either kind of electricity, the other side of the pane will acquire, proportionably, a charge of the opposite nature.

EXPERIMENTAL ILLUSTRATIONS.

A dry glass pane is held in one hand by an insulating handle. Sparks are taken from the excited conductor of an electrical machine, with the knuckle of the other hand. The glass pane, being interposed between the knuckle and the conductor, at first does not appear to intercept the sparks—yet, as they gradually diminish, and finally cease, they are obviously intercepted by the pane, sooner or later. The pane being suspended by the handle—on touching the surfaces in the part which has been exposed to the sparks, with one hand, while the part opposite on the other side of the pane is touched by the other hand, an electrical discharge takes place, a shock is experienced, and the electrical excitement disappears.

DEDUCTION.

It follows, that the sparks which had apparently passed through the pane, had actually been arrested by the surface nearest to the conductor, and had appeared to reach the hand—because, for every spark received on one side, an equivalent portion of the electric fluid is expelled in the same form from the other side.

EXPERIMENTAL ILLUSTRATIONS RESUMED.

A pane of glass is coated on both sides with tin foil, excepting a space of about two inches from the

edge all round. The two coatings are made severally to communicate, for a short time, with the two insulated conductors of an electrical machine, while in operation—the coatings being otherwise insulated. The pane being then suspended, and the different coatings severally allowed to communicate through a metallic arc, a discharge ensues, more or less powerful, according to the power of the machine, the extent of the coated surface, and the dryness of the air.

Analogous experiment, made by means of a glass jar, coated on the inside and on the outside, till within two or three inches of the brim: called the Leyden Jar.

The metallic instruments, called Dischargers, employed in discharging coated surfaces, exhibited and explained.

EXPERIMENTAL PROOFS, THAT THE DIFFERENT SURFACES OF A CHARGED ELECTRIC, ARE OPPOSITELY ELECTRIFIED.

A Leyden jar, suspended by a metallic hook, connected, with one of its coatings, from conductor of the electrical machine, while in operation, receives no charge, until the other coating is approximated by a conducting substance, which communicates directly, or indirectly, with the other conductor of the machine.

A light body, as, for instance, a pendulum, or a small bell clapper, is suspended between two bells, communicating with the different coatings of a Leyden jar----the jar being previously charged. If at a proper distance from each bell, the clapper will be alternately attracted to each; showing, thus, that the coatings with which they communicate, are oppositely electrified.

A Charge is imparted, equally well, by the contact, or communication, of either Coating, with either Conductor.

When a coating is in contact with the negative conductor, electricity being abstracted from that surface, an equivalent portion is accumulated on the other surface; whereas, when a redundancy is produced, by the machine, by a contact with the positive conductor, a proportionable deficiency arises in the other surface, as has already been stated. The absolute quantity on both sides of the pane, being the same always—and hence charging the pane, does not derange the electrical equilibrium in the surrounding medium.

EXPERIMENTAL ILLUSTRATIONS.

That the charges may be imparted through either coating, by either conductor, shown, by duly charging, and discharging, coated panes, and jars.

Metallic Coatings employed, as in the preceding Experiments, are of use in conveying the Charge—but it does not reside in them.

The effect of the tin foil, is, simply, to cause the speedy and equal distribution of the electricity over the surface of the glass, which, not being an electric, cannot by itself convey the excitement from one part of its surface to another.—Hence a pane without coatings, can only be partially charged or discharged at one contact.

That the charge does not reside in the coatings, may be proved by removing them, touching them with the hand while separated from the glass—and afterwards replacing them, and simultaneously touching them. A shock will be received, in the same way as if they had not been removed.

Any other metallic covering, which will accommodate itself to the surface of the glass, may be used, in lieu of tin foil.

A glass vessel, filled with water to a due height, and moistened to the same height on the outside, may, as in the celebrated experiment of Cuneus, and Mushenbrœck, be charged and discharged, by the same means as the pane or phial coated with tin foil, though less advantageously.

Gold, silver, or copper leaf, metallic filings, or mercury, may be substituted for the coatings of a Leyden jar. When metallic filings are glued to the surfaces of a pane or jar, within the space usually allotted to the tin foil coatings, the discontinuity of the conducting surfaces, causes the passage of the electricity from one portion, to another, to become visible, and productive of a beautiful and interesting appearance.

EXPERIMENTAL ILLUSTRATIONS.

A glass pane, held by its insulating handle, is made to touch the knob of an excited conductor of the electrical machine, on one side----while another metallic knob, communicating with the other conductor of the machine, is made to touch the pane on the other side, in the part opposite to the first mentioned knob. By varying the situation of the knobs, the pane is charged, wherever its surfaces have been sufficiently in the vicinity of the knobs. While thus prepared, it is suspended by its handle, and one hand of the operator approximated to one side, while the other hand approximates the other. It can only be gradually discharged, as it was charged; the hands being made to assume, successively, the various positions relatively to the pane, previously occupied by the knobs. But, the pane being again charged by the knobs and coatings, duly applied; the surfaces are thoroughly and instantaneously discharged at once, by the contact of the hands, or other competent conductor. The coatings being applied to the

pane, whilst charging, and then removed, the discharge can only be effected gradually.

Pane of glass charged by means of thin sheets of iron, in lieu of tin foil.

Charge and discharge of glass vessel, partially filled with water, and duly moistened on the outside:----also of Leyden jar, coated externally with metallic filings:----also of a jar, coated internally with Dutch gold leaf.

Glass tumbler with moveable coatings, charged. The coatings being removed, and replaced, the tumbler is then discharged, as if the coatings had remained.

OF ELECTRICAL BATTERIES.

A series of coated jars, being placed side by side in a box, and all the inner coatings being made to communicate with each other, and with a ball of metal, by means of metallic rods—and all the outer coatings being made to communicate with eaah other, and with another metallic ball, by strips of tin foil; the jars, thus associated, are called an Electrical Battery.

Charging and discharging an electrical battery, however extensive, is just as simple, and is performed in precisely the same way, as in the case of a single jar. To charge a single jar, or a battery, the different coatings must be made to communicate, severally, with the different conductors of an electrical machine, either directly or indirectly, through the floor of the apartment, or other conducting medium.

To effect a discharge, either one or several conductors must be made to form a circuit from one coating to the other, either unbroken—or, if interrupted, the interval, or the sum of the intervals, must not exceed a certain distance, called the striking distance, and which varies with the extent and intensity of the electrical machine.

Charging a battery, will take more or less time, according to the number of jars to be supplied, and the quantity generated by the machine. But the discharge appears as quick from one hundred, as from one—notwithstanding the numerous ramifications, through which the electricity has to pass.

EXPERIMENTAL ILLUSTRATIONS.

Electrical Battery of 48 jars, containing 45 square feet of coated surface, exhibited and explained: also charged, and discharged. Wire deflagrated.

OF ELECTRICAL EXCITEMENT BY INDUCTION.

The simplest case of this kind, is that of the Leyden phial, or coated pane, already illustrated—where one surface, being in contact with an excited conductor, a tendency is induced in the electricity, on the other side of the electric, to leave it. This, probably, arises from that self-repellent power, between the particles of the electrical fluid, with which Franklin supposed them to be endowed.

If the outer and inner coatings, of two or three insulated jars, be made to communicate—and the coatings of each extremity of the series, be brought into communication with the conductors of a machine in operation, as usual when one jar is to be charged—it will be found, that a charge is received by all; and in discharging them, a spark may be perceived to pass between each jar, if a small interval be left. The aggregate of the charge, is no greater than that which would be assumed by one jar. In this case, the surfaces are said to be charged by *induction;* that is, the charge given by the coating of the first jar, forces electricity from the other side of the glass into the next jar. This redundancy has a similar influence upon the third jar, and the jar next beyond it. It will be found to lessen, as it proceeds; so that the number

of jars which can be thus affected, is greater, or less, according to the intensity of the electricity evolved by the machine, and the aggregate thickness of glass interposed.

From a plate of mica, duly coated, and charged, a shock, far more severe, may be obtained, than from an equal extent of coated glass; because the glass is fractured, if as thin as the mica—and when thick enough to resist, the self-repellent power of the electric particles, which causes the jar to be charged, acts with less force, owing to the greater distance.

OF THE MEANS OF DETECTING ELECTRICITY.

It has been seen, during my experimental illustrations, that the property which light bodies have, of separating from, or approaching to, each other, when electrified, has been of use in showing the nature, and extent of electrical excitement.

A ball of pith, supported by a radius, which hangs on a pivot, so as to be capable of describing an arc of 90 degrees, over a corresponding curved scale—constitutes Henley's Quadrant Electrometer, employed in the experimental illustrations, page 11.

Bennet's Electrometer, has been already exhibited; in which, metallic leaves are suspended, within a glass cylinder, to a metallic cap—slips of tin foil are pasted on the glass, opposite, and parallel to, the gold leaves.

This last mentioned instrument, is sometimes, more properly, called an Electroscope—as it is better calculated to discover electricity, than to measure it.

The efficacy of the gold-leaf electroscope, is much increased by the addition of two vertical disks, one soldered to the cap, the other to the foot, by a hinge—so as that it may be placed parallel, and as near to the first mentioned disk as it can be, without touching. In this case, the capacity of the disk, attached to the cap, for electricity, is found to be increased, by *induction*—so that it will receive a surcharge. When the

disks are separated, the excess of electricity received, while they were near each other, is indicated by the divergence of the leaves.

I have constructed an electroscope with a single leaf, to which a brass ball may be approximated by a micrometer screw. This is more sensitive, than any electrometer which I have seen on the usual plan. When furnished with a cap of zinc, if a plate of copper be placed on the cap, and then lifted, the leaf will strike the ball.* This instrument, acts both as an electroscope, and as an electrometer—as it detects and measures the minutest degree of excitement.

EXPERIMENTAL ILLUSTRATIONS.

Henley's Electrometer....the common Gold-leaf Electrometer....the Condensing Electrometer....and the Single-leaf Electrometer....exhibited. Electricity, produced by the repeated contact and separation of metallic disks, shown, by means of the condensing apparatus: also indicated by the single-leaf electrometer.

OF THE EFFECTS OF ELECTRICITY.

Allusion has been made already, to some of the most important effects of the electrical fluid. The approximation and separation of light bodies—the extrication of light and heat—the shock given to the animal frame—have all been, more or less, the topics of discussion, or experimental illustration;—and it is under these heads, that all the effects of electricity may be arranged.

Having, heretofore, treated of them, to a limited extent only, and as secondary to other objects more especially in

* See Appendix, for a plate and description of this instrument.

view at the time—I shall now show them in greater variety; and, where the results, being more complicated, render an undivided attention necessary, in those who would comprehend them.

OF ELECTRICAL ATTRACTION.—OF ELECTRICAL LIGHT.—OF ELECTRICAL IGNITION.—OF THE ELECTRIC SHOCK.

OF ELECTRICAL ATTRACTION.

Under this head is placed both the separation and approximation of light bodies, when electrified; since the former, though commonly ascribed to repulsion, is really, as I conceive, the effect of attraction.

In an essay, on the question, whether there be two electric fluids, or one—which will be printed in the Appendix to this Supplement—my reasons for this impression are given at length.

ADDITIONAL EXPERIMENTS, DEMONSTRATING THE EXISTENCE, AND THE NATURE, OF ELECTRICAL ATTRACTION.

Experiment with the bells, repeated, by means of conductors of the electrical machine.

Electrical tree, whose branches are made to revolve.

Dance of figures made of pith: also electrical hail, by means of pith balls enclosed in a glass cylinder.

Revolution of the sun, a planet, and its satellite, imitated.

RATIONALE.

In the case of the bells, and figures of pith, the movements are produced by the attraction of the differently excited surfaces, above and below.

In the case of the revolution of the branches of the electrical tree, and of the planet and its satellite, the motion results from the attraction of the surrounding medium, successively operating at each point of the orbit, to separate the electrified air from the body by which it is electrified.

OF ELECTRICAL LIGHT.

ELECTRICAL LIGHT IN PLENO.

Sparks taken in the dark from each conductor of the Electrical Plate Machine.* Electrical brush exhibited.

Pieces of tin foil are so placed, in succession, on a glass pane, as to leave minute intervals between each, and to exhibit the electric light, in the passage of the fluid from one excited conductor to another, at every interruption of the conducting metallic surface.

Splendid effect of glass columns prepared with tin foil, in the same way as the panes above mentioned. A swivel of wire, terminating in knobs, is so swung, that, when charged, it revolves from the brass knob of the column to which it is nearest, to that of the next—and thus successively conveys to each, the sparks imparted to it by the Machine.

Eggs internally illuminated.

ELECTRICAL LIGHT IN VACUO.

Bell glass and globe exhausted, and electrified.... and the difference shown, between the light caused by the positive and negative influence.

* An engraving and description of this machine, will be given in the Appendix.

ELECTRICAL IGNITION.

Ether, cotton, and hydrogen, inflamed by the electric spark.

The electric discharge, shown to be incapable of igniting charcoal.

OF THE ELECTRIC SHOCK.

This effect of the electrical fluid, is subsequently treated of, in illustrating the mode of electrifying a patient.

OF MITIGATING THE EFFECTS OF ELECTRICITY.

The same charge of electricity, which would produce a shock, or deflagrate a wire, if received through a knob, may be insensibly received through a fine point. The power of an electrical machine, or that of a large battery, is thus easily paralyzed. Hence the employment of pointed rods of metal, as a protection against lightning. Hence, also, it is necessary, in the construction of electrical apparatus, to avoid all edges or acute projections, unless where it is intended to facilitate the passage of the fluid.

RATIONALE.

When a knob is approached to an excited conductor—as soon as any portion of it is near enough to be struck, so much of the ball is at hand, as to allow the whole discharge to take place at once;—but, when the apex of a pointed wire is near enough to receive a portion of the fluid, the other parts are too remote to come into action; and whether the point advances to the electrified body, or the body approximates the point, the

fluid is discharged before it is within striking distance, of the thicker part of the wire. The point being always the foremost, the electricity escapes through it, faster than it can be approximated, to any negative body or medium.

In fact, the difference between a discharge by a point, and through a knob, is the same as that which exists between making an auger-hole in a reservoir to let out a fluid, and opening a floodgate.

OF THE PROPER MODE OF CONSTRUCTING, AND PUTTING UP, LIGHTNING RODS.

The competency of pointed rods, to protect us against lightning, is dependent, not merely on the excellence of the point, which should be of platina, but on the mode in which joints in the conductor are made, and the nature of the soil in which it terminates. If a wire, pointed at one end, be blunt at the other, and the nearest conductor to the blunt end be not pointed, the charge will not pass off gradually, because received at a point. Moreover, the power of a conductor to receive the electric fluid, is compounded of its own conducting power, and that of the medium in which it terminates.

A metallic rod, terminating in a glass handle, or in powdered glass, or dry sand, would not operate as a conductor. It cannot receive electricity, because it cannot deliver it.

Moist earth is but an imperfect conductor—since it owes its faculty, of conducting, to water, which conducts with 200,000 times less facility than iron.

Lightning rods should therefore be connected, by soldering, with an extensive metallic surface buried under the earth, as for instance, with sheets of lead, or copper.

The cases, in which conductors have been alleged incompetent, are, I am satisfied, referrible to their inadequate communication with the earth.

Effect of a point shown, in drawing a charge from a battery, or conductor:—proved, also, that its power is weakened, or destroyed, by being associated with an electric, or imperfect conductor.

ADDITIONAL MEANS OF PRODUCING ELECTRICITY.

OF THE ELECTROPHORUS.—OF ELECTRICITY, EVOLVED BY PRESSURE, BY CHEMICAL CHANGES, AND BY THE CONTACT OF HETEROGENEOUS METALS.

OF THE ELECTROPHORUS.

Let there be a cake of resin, the upper surface being as true a plane as can conveniently be made: also a metallic disk an inch or two less in diameter than the cake, with a glass handle cemented into a metallic socket, so that it may be held either by the socket, or the glass. Let the resin be rubbed with a dry cat's skin, then holding the plate by the socket, place it upon the resin—afterwards lift it by means of the glass handle, and bring the other hand near it. A spark will be received by the hand thus presented to the disk.—Replacing the disk on the resin, in the same way as at first, another spark may be had in like manner; and by a repetition of the process, sparks may be produced for a great length of time.

An electrophorus, being well excited in dry weather, will give sparks for many weeks, without being rubbed again.

RATIONALE.

The resin, being negatively excited by the friction—when the plate is laid down upon it, the electricity is less repelled on the side towards the negative surface, than externally, where there is no deficiency; it therefore flows into the plate, and charges it redundantly. When the plate is lifted, the proximity of the resin, which caused the redundancy, ceases, and of course the excess is given off, as soon as a conducting medium affords the opportunity.

A cake of resin, with a disk to create this species of excitement, is called an Electrophorus.

EXPERIMENTAL ILLUSTRATIONS.

Electrophorus exhibited, and explained. Method of exciting it, and obtaining sparks from it, shown.

OF ELECTRICITY EVOLVED BY PRESSURE.

There are many substances, wnich, if placed upon the disk of an electrometer, and pressed, will, on the cessation of the pressure, evolve enough electricity to be indicated by the gold leaf.

OF ELECTRICITY EVOLVED BY CHEMICAL CHANGES.

Among the sources of electricity, meteorological changes are by far the most prolific. When we compare thunder, with the noise of an electric discharge, whether from a conductor, or from a battery, we feel the comparative insignificance of electrical phenomena, artificially produced. Nor is the comparison more favourable, when a spark of a few inches in length, is contrasted with a forked flash of lightning, extending as many hundred feet.

But, whatever may be the disparity, between the phenomena of thunder and lightning, and those, of electrical discharges, produced by human ingenuity—I believe, no other difference is supposed to exist between them, by any electrician.

The assumption of the vaporous, or gaseous state, in many instances, appears to be satisfactorily accounted for, by supposing a union of ponderable matter, with caloric. Yet, the power of the electric spark, in effecting a union of the elements of water, of nitric acid, or ammonia; the explosive evolution of the oxygen, from oxygenated water, by the presence of oxide of silver; the inflammation of hydrogen, by platina sponge; prove, that there is much yet to be learned, respecting the association or reaction of imponderable agents, and of the part which they perform, in creating, or condensing aëriform matter.

It would seem, from the phenomena of thunder gusts, that the condensation of aqueous vapour, must cause the evolution of electricity, as well as of caloric. It is in this way only, that a destruction of the electrical equilibrium, can be imagined to arise, adequate to cause an emission of sparks from the clouds to the earth, so tremendous in effect.

Volta observed, that when coals are placed in a metallic recipient, on the cap of an electrometer, and sprinkled with water, the leaves are negatively electrified; while a metallic vessel, which condenses the vapour as it rises from the coals, becomes positively electrified.

Franklin, it is well known, drew electricity from the clouds, by means of a kite. Richman, of Petersburgh in Russia, lost his life, in operating with an apparatus, for the same purpose, which entered his apartment. Beccaria was not, by this, deterred from repeating the experiment, by means of a wire, of more than one hundred feet in length, at one time—and at another, by a rope, fifteen hundred feet in length, stretched over the river Po.

A wire, a mile long, insulated on poles one hundred feet high, is mentioned, by Singer, as having been erected by Crosse, an enterprising electrician. This wire communicated with an appropriate apparatus, in an apartment of the owner's house. The account of the phenomena which it produced, is very interesting. I give it in Mr. Singer's words :—

"The approach of a charged cloud produces sometimes positive and at others negative signs at first; but, whatever be the original character, the effect gradually increases to a certain extent, then decreases, and disappears, and is followed by the appearance of the opposite signs, which gradually extend beyond the former maximum, then decrease, terminate, and are again followed by the original electricity. These alternations are sometimes numerous, and are more or less rapid on different occasions; they usually increase in intensity at each repetition, and at last a full dense stream of sparks issues from the atmospherical conductor to the receiving ball, stopping at intervals, but returning with redoubled force. In this state a strong current of air proceeds from the wire and its connected apparatus; and none but a spectator can conceive the awful though sublime effect of such phenomena. At every flash of lightning an explosive stream, accompanied by a peculiar noise, passes between the balls of the apparatus, and enlightens most brilliantly every surrounding object, whilst these effects are heightened by the successive peals of thunder, and by the consciousness of so near an approach to its cause."

OF ELECTRICITY EVOLVED BY CONTACT OF HETEROGENEOUS METALS.

If a disk of copper, and a disk of zinc, be brought fully into contact with each other, face to face, from ten to twenty times—and after each contact, the copper disk be made to touch the cap of a condensing electrometer—it will be found, on separating the condensing disks of the electrometer, that the gold leaves will diverge.

This phenomenon may be rendered evident, without a condenser, in a mode first resorted to by me—and which, together with the instrument contrived for the purpose, will be described in the Appendix.

When a series of disks of zinc, with Dutch gold or silver paper—or paper, silvered on one side, and coated on the other with manganese and sulphate of zinc—are alternated in a pile of many thousand; the extremities of the series will be found, permanently in opposite states of electrical excitement;—so that a needle will vibrate between them for several years.

This wonderful instrument will be again treated of, under the head of Galvanic, or Voltaic, Electricity.

I have found, that, by twelve plates of copper, alternated with a like number of zinc plates, and separated into pairs by pieces of paper, a movement might be produced in the single-leaf electrometer.

THEORETIC EXPLANATION OF ELECTRICAL PHENOMENA.

It may be proper, to give the rationale of the production, accumulation, and neutralization, of Electricity—agreeably to the doctrine of two fluids.

Much to my surprise, this doctrine has, within the last twenty years, been gaining in credit, especially on the Continent of Europe. Under these circumstances, it merits attention, whatever may be its intrinsic importance.

OF THE THEORY OF TWO FLUIDS.

According to this hypothesis, when a body is electrically excited, a neutral compound, formed of two electrical fluids, is decomposed—one is retained by the excited body, the other is given off. The fluid retained by excited glass, is given off by excited resin; and vice versa—that which is re-

tained by resin, is given out by glass. Hence, according to this theory, no less than Franklin's, the two electricities are always produced both by resin and glass; though the fluids retained in them respectively, being, in the first instance, separately recognized and associated with the substances in which they were observed, were named accordingly.

When a portion of a glass cylinder, or plate, is rubbed against a cushion, it gives off resinous, and receives vitreous, electricity. This surcharge of the vitreous fluid, is retained by the excited surface, until, in revolving, it comes opposite to the conductor. The increased capacity, created by the friction, ceasing, an equalization of the electricities, between it and the conductor, ensues; by which, the excitement is reduced, more or less, according to the extent of their respective surfaces. Returning to the cushion, the glass is re-excited, to the same degree, as it first; and, by a continuation of the process, gradually causes an exchange of vitreous for resinous electricity, between the conductors, until they are electrified, as oppositely, as the performance of the machine will permit.

Under these circumstances, if a conducting communication be made, between the oppositely excited bodies, the electricities rush together—neutrality ensues, and a total cessation of electrical phenomena.

The union of the two fluids, is supposed to be productive of the evolution of heat and light, which they absorb while separated.

In charging a Leyden jar, the two coatings become, for the time they are in communication with the conductors, respectively, a part of them. That which touches the resinous, or negative conductor, therefore, gives up its vitreous electricity, and receives resinous—while an opposite exchange, of resinous for vitreous, takes place in the other coating. When the charge is completed, the opposite electricities attract each other, through the glass, so as to keep each other on the surfaces which they respectively occupy; of course, a re-

moval of the coatings, does not cause a removal of the charge.

When the extremities of a metallic arc, are made severally to approximate both surfaces at once, the resinous electricity is attracted out of the end near the coating, vitreously charged —while the opposite effect takes place, at the other end of the arc. Thus, by a series of decompositions, and recompositions—or by currents, passing each other, like the wax-ends of the cobbler—the different surfaces are restored to their previous state.

ADDITIONAL REMARKS, EXPLANATORY OF FRANKLIN'S HYPOTHESIS.

According to the theory of Franklin, the effect of an electrical machine, in drawing electricity from the cushion, and surfaces connected with it, and accumulating it in those in communication with the opposite surface of the glass cylinder, has some analogy with that of a wheel, or pump, for raising water. And the effect of the metallic arc, in discharging the surfaces, may be compared with that of a syphon, in producing a level in reservoirs of water—excepting, that the velocity of the electric current is incomparably greater.

The increased capacity for the electric fluid, arising from friction in the glass, operates like a bucket on a wheel, to enable it to receive a portion of fluid—and the loss of this capacity, after the friction ceases, is analogous to that inversion of the buckets, which causes them to be emptied, at every semi-revolution.

RATIONALE OF ELECTRIC LIGHT AND IGNITION.

It appears evident, that there is a reaction between heat, light, and electricity.

It is not surprising, therefore, that the presence of one, should cause the appearance of either of the others—since they all, evidently, pervade nature. It may be conjectured, that the electric fluid is luminous, when projected, with

intensity, into the air, in consequence of its carrying, along with it, the light encountered in its progress through ponderable matter. In like manner it may cause the extrication of caloric, by displacing it, when latent—or by adding temporarily to its repellent power, it may enable it to overcome attraction of cohesion;—in which case, a metal, no doubt, contains caloric enough to produce a violent, or even explosive, separation of the metallic particles.

ON THE QUESTION, WHETHER THERE BE TWO ELECTRIC FLUIDS, OR ONE ONLY.

This question has been discussed, in an essay which I published about eighteen months ago, in the Philadelphia Medical Journal, and which will be found in the Appendix to this Supplement.

I shall now confine myself, principally, to elucidating it by experiments.

EXPERIMENTS, TO ELUCIDATE THE QUESTION, WHETHER THERE BE TWO ELECTRIC FLUIDS, OR ONE.

Experiments with electrometers, in pleno, and in vacuo.

Electric spark, when emitted from a small knob from the positive conductor, compared with a spark obtained from the same, or a similar knob, attached to the negative conductor.

Positive and negative sparks, in vacuo, shown to be different—and that the difference is favourable to Franklin's hypothesis.

Exhibition and explanation of machine, with two glass cylinders, for demonstrating, that positive and negative electricity, are relative states of the same fluid.

Of three conductors, Nos. 1, 2, 3, it is shown, that No. 2 is vitreous, when tested by No. 1—but that, when tested by No. 2, it is resinous.

Sparks, passing between a neutral body and a conductor, positively or negatively excited, shown to differ only in length, from those which pass between oppositely excited conductors.

MEANS OF ELECTRIFYING PATIENTS, EITHER WITH SPARKS, OR BY SHOCKS.

A person, seated on an insulated chair, is made to communicate with one of the conductors; being thus negatively or positively electrified, sparks may be taken from any part of the body, by a metallic knob, or point. If the knob be too severe, the point may be used; and if this be too powerful, it may be covered by a wooden cone.

In order to subject a person to shocks, a coated jar is used, with two knobs—one connected with the inside coating, the other supported on an insulated wire, so that it may be made to approach, or recede from, the knob which communicates with the inner coating. To the outer coating, and the insulated knob, chains are attached, each terminating at one end in a knob of metal with an insulating handle. The handles are held by the operator, and the knobs applied to the patient, so as to leave between them, the part to be electrified. The coatings of the jar being severally connected with the different conductors, of an electrical machine, the charge increases in the jar, until it becomes strong enough to strike through the interval between the knobs connected with the inner coating, and that insulated in its vicinity. Of course, the height of the charge, depends upon the interval thus left—pursuant to the operator's discretion, or the feelings of the patient.

EXPERIMENTAL EXHIBITION OF THE METHOD TO BE PURSUED, IN ELECTRIFYING A PATIENT, WITH SPARKS, OR BY SHOCKS.

Insulating stool, and knobs, with insulating handles, exhibited. Sparks taken from a person, duly insulated, and excited.

Jar, with insulated knob, and chains, and knobs, with glass handles, produced. Shocks given, by means of this apparatus, as above described.

ON THE ORIGIN AND PROGRESS

OF

GALVANISM, OR VOLTAIC ELECTRICITY.

WITH Franklin's discoveries, the science of mechanical electricity had attained its meridian splendour. Subsequently, many years had elapsed, without any very important advance in that branch of knowledge. In the interim, the wonders of pneumatic chemistry, had occupied the most sagacious and ardent, among the cultivators of experimental science; and their brilliant discoveries had attained the zenith, when, fortuitously, the genius of investigation met with a new impulse.

It had been previously known, that when pieces of different kinds of metals, are placed above and below the tongue, their extremities projecting beyond it, and brought into contact, a pungent taste would be excited.

No further investigation took place, until Galvani, an Italian physiologist, engaged in the dissection of frogs, in order to explain the cause of convulsions which had been observed in those animals, when prepared for soup, and placed near an electrical machine. He ascertained, soon afterwards, that

the simultaneous contact of different metals, which had previously been found to excite taste, when operating on the tongue, would, in frogs, produce convulsions. This he explained, by supposing the nerve, and the muscle, to be in opposite electrical states, analogous to those of the surfaces of a Leyden jar—the metal operating merely as a discharger.

His countryman, the illustrious Volta, soon demonstrated, that the influence was produced by the metals on the animal —not by the animal on them; and that the cause of the sensation produced on the organ of taste, by one pair of metallic plates, could, by their accumulation, be made competent to shock the whole animal frame.

The pile thus contrived by Volta, which has immortalized his name, and produced results surpassed by no other invention, consisted of disks of copper and zinc, alternated with each other and with pieces of moistened cloth, which separated them into pairs, consisting of one disk of each metal.

On touching, simultaneously, the extremities (called poles) of such a pile, when consisting of one hundred pairs, a shock is experienced, which becomes more severe as the number is increased, and is extremely painful from a pile comprising more than three hundred pairs.

A series, the same in principle, was afterwards made in another form, called the Couronne des Tasses; disks of copper and zinc being soldered to arches of wire, so as to be consecutively immersed in adjoining tumblers, in the same alternate order as in the pile. In this apparatus, the communication established between the metallic disks, by the arches of wire, was substituted for the actual contact, of the metallic surfaces, in the pile; and the water in the tumblers, answered in the place of the moisture in the interposed pieces of cloth.

The Voltaic apparatus, passing into the hands of the English chemists, was found capable of effecting chemical decomposition. Water was resolved into its gaseous elements, by wires immersed in it, and duly connected with the poles.

Cruickshank modified the apparatus, into a form, more powerful, by causing plates of zinc and copper, soldered face to face, to serve as partitions in troughs; the copper and zinc surfaces, alternating regularly with each other, and with a liquid occupying the cells, or interstices between them.

A construction, intermediate between that of the Couronne des Tasses, and the Trough, was finally adopted and used by Sir Humphry Davy. A porcelain trough was constructed, with cells, resembling those of the Cruickshank trough—but the metallic plates were united by arches of metal, as in the case of the Couronne des Tasses; and were suspended to a beam, in the same order, so as to be immersed in an acid in the cells of the trough, or lifted out of it, at pleasure. Each trough was made for ten pairs—but any number were associated, by means of arches connecting a copper and zinc disk, severally immersed in cells, of the troughs united by them.

A series of this kind was constructed at the Royal Institution, containing two thousand pairs. This construction, while equally powerful with that of Cruickshank, is more convenient, and is generally preferred, as the plates may be more easily removed from, or replaced in, the troughs.

When, instead of merely moistening the interposed disks of cloth, or supplying the cells with water, salts or acids were used, the Voltaic series was found vastly more powerful, in producing ignition, or decomposition.

Volta had attributed the powers of his pile, to an accumulation of electricity. He showed, that, after contact with each other, a copper plate would be found in the negative state, and a zinc plate in the positive state, of electrical excitement. The surcharge of electricity, thus attributed to the contact of the first plate of copper, with the first plate of zinc, was supposed to be conducted to the second plate of copper, through the moistened cloth, or interposed stratum of fluid. The greater effect, resulting from the interposition of acids, was ascribed by him to their greater conducting power.

By some other chemists, it was supposed, that the chemical action of the acids, or water, evolved electricity from the metals. This idea derived plausibility, from the obvious necessity of chemical action to the Galvanic current; but it was opposed in its extent, by the circumstance, that it did not explain why this chemical action should take place more powerfully, in consequence of the Galvanic arrangement:—why the presence of copper, should cause zinc to be more rapidly corroded. Moreover, the effect was not proportionable, to the intensity of the chemical action. It was in support, however, of this chemical hypothesis, that Wollaston constructed his elementary battery—by which, he showed, that a morsel of zinc, placed within a lady's thimble, containing a few drops of weak acid, would cause the fusion of a very minute platina wire.

Could he have proved, that the fusion was caused by electricity alone, he would indeed have shown a prodigious evolution of that fluid, from the solution of a metal.

Some other philosophers, among whom was Sir Humphry Davy, considered a polarity consequent to an electrical accumulation in the zinc plates, to be the first step in the process; that each polar arrangement thus produced, acting on the next, through the fluid, by induction,* a difference arose at the poles of the series, which was a multiple of that produced by the members severally. Thus, according to this doctrine, the fluid does not, in the first instance, act by its conducting power, as Volta supposed; but, on the contrary, in consequence of the low intensity of the electrical excitement, serves the purpose of a non-conductor. The next, and a necessary, step, for the production of a Galvanic current, agreeably to this hypothesis, is the action of the menstruum in dissolving the excited metal, and thus evolving the electricity exciting it, which is thus continually extricated at the poles, so long as any conducting communication is kept up between them. Without this communication, the extri-

* See page 17 of these Lectures.

cation of the electricity must cease, as soon as the accumulation at the poles becomes as great as it can be rendered, by the actual energy of the series. In this theory, the fluid is supposed to act, at first, as a non-conductor, in the next place, as a conductor—and no reason is given for the difference.

Moreover, Sir H. Davy, while he alleges, that the action of the fluid, in Galvanism, is upon atoms, instead of upon masses, agreeably to the wonted habitudes of the electric fluid—admits, that he can give no reason for this difference.

De Luc adopted Volta's view, of an electromotive power in the Voltaic series, independently of the chemical action of interposed agents; but, considered the oxidation of metals, as necessary to produce the shock, or chemical decomposition. —In support of his views, he constructed a very interesting apparatus, called the Electric Column; consisting of pieces of Dutch gold or silver paper, alternating with zinc. A series, thus formed, when extended to some thousands, gives sparks, and charges a Leyden jar—or produces vibrations in a pendulum interposed, by the opposite electrical attractions of its different poles.

It had been observed, that when Galvanic plates, of six or eight inches square, were employed, though not in a numerous series, the deflagration of metals might be produced, while the shock from them was hardly perceptible. Mr. Children, in consequence, made a series of twenty triads—two plates of copper enclosing one of zinc, and each sheet six feet by two feet eight. The effects of this combination, on metals, were prodigious. Five feet six inches of platina wire, of more than the tenth of an inch in diameter, were heated red hot. Other results, equally striking, were obtained.

About the same period, Sir H. Davy, by a more numerous, but smaller series, effected the decomposition of the alkalies and earths. When charcoal points, affixed to the poles of a series of two thousand pairs, constructed by him at the Royal Institution, were first brought nearly into contact, and then removed a few inches apart, an arch of igneous matter was

produced, by which the most refractory substances were either dissipated, or fused. In vacuo, the luminous arch between the points was extended to seven inches.

These experiments of Davy, and Children, rendered it evident, that the severity of the shock, and the divellent action of the wires attached to the poles, in decomposing substances exposed to them, was greater, in the same extent of surface, when divided into many small pairs; but that, when arranged in large pairs, its calorific influence, in deflagrating or igniting metals, would be superior.

I have already mentioned the discordant hypotheses, proposed to explain the evolution of the Galvanic principle. A coincidence of opinion, however, generally existed, respecting its nature. The same fluid was supposed to be extricated by Galvanic apparatus, and by the electrical machine; mechanical electricity, being less copiously, but more intensely, evolved, than Galvanic. In like manner, the difference between the fluid extricated by Children's apparatus, and that produced by a numerous series of small plates, was ascribed to the quantity being as the size—the intensity, as the number.

To me, this explanation of the nature of the Galvanic fluid, and the theories of its production, have both appeared unsatisfactory. The extreme rapidity with which the electrical fluid, however deficient of intensity, is carried off by moisture, has appeared an insurmountable obstacle to its being accumulated, per se, by an apparatus, in which moisture prevails.

From the prodigious heat excited at the Galvanic poles, caloric, no less than the electric fluid, seems to form a part of the stream; and, as the influence of this principle is exerted between atoms, and as it cannot pervade fluids by the conducting process, unless in an insignificant degree—it has appeared to me, at least, as reasonable, to consider it an original product of Galvanic action, as to derive the other fluid from this source. The quantity of the two principles evolved,

appears to vary with the apparatus producing them: the caloric being to the electricity, as the extent of the generating surface to the number of the series. In the case of batteries, in size and number, intervening between Children's great apparatus, and the two thousand pairs of the Royal Institution, both fluids are supposed to influence the results. In De Luc's column, I conceived the influence of caloric to be evanescent. Hence there appeared room for another arrangement, in which caloric should prevail, and electricity be evanescent. I therefore constructed a very large Galvanic pair of twenty sheets of copper and zinc alternating—expecting, that in this apparatus, the phenomena would be the opposite of those in De Luc's column—and that, as in a series where the number reached many thousands, the size of the members being insignificant, no agency of caloric could be perceived: so, in an arrangement, where these characteristics might be inverted, the results would be reversed, and heat would appear without electricity. The issue corresponded with my expectations; heat was excited in great quantity, unaccompanied by any greater indication of electricity, than a small pair, of an inch or two in superficies, might evince. The pair thus made by me, contained about fifty square feet.

Mr. Peale, afterwards, made a similar instrument, a third larger; and Mr. Wetherill made one twice as large. The projectile power arising from electricity, was found to lessen, as the size was increased.

Charcoal, so easily ignited between the poles of Mr. Children's apparatus, was not affected by mine. Volta had called the Galvanic plates, as used by him, *Electromotors*, or movers of electricity. I called mine *Calorimotors*, or heat movers.

Next, in order to vary the experiment, I made an apparatus of four surfaces, to be immersed in one recipient, as my calorimotor, of two surfaces, had been before. There was an evident accumulation in the projectile power, by this arrangement—since a small wire could be heated more intensely.

EXPLANATION

AND

EXPERIMENTAL ILLUSTRATION

OF

GALVANISM, OR VOLTAIC ELECTRICITY.

ILLUSTRATIONS.

Disks of zinc, provided for the purpose of producing a Galvanic discharge through the tongue, when severally placed above and under it—the projecting limb of each disk being brought into contact.

A plate of copper, and a plate of zinc, being connected by a small wire, and plunged into a vessel containing a dilute acid, the ignition of the wire is produced. The same result obtained, by concentric coils of sheet copper and sheet zinc: also by several plates of copper and zinc, alternated with each other—all the copper plates being associated in one metallic superficies, and all the zinc plates in another. These heterogeneous surfaces have, every where, interstices between them, and are connected only by a small wire, which is deflagrated, as soon as they are immersed in an acid contained in a proper receptacle.

A candle lighted, and gas exploded, by Galvanic ignition.

EXPLANATION OF THE TERMS GALVANIC PAIR, AND CALORIMOTOR, AS USED IN THESE LECTURES.

A copper and zinc superficies, duly associated, so as to produce a Galvanic discharge, are the same, in principle, whether they consist of two plates, one of each metal, parallel to each other—of sheets of the different metals, coiled up concentrically—or of several plates alternated, all the copper plates being united by a metallic communication, and all the zinc plates united in like manner. I consider any number of homogeneous plates, thus communicating by a perfect conductor, as one Galvanic surface. Hence I apply the term, Galvanic Pair, to designate any of the apparatus, employed in the Galvanic illustrations already given.

Such pairs, when associated in a pile, were, by Volta, called *Electromotors*, or movers of electricity; though, I think, experience has shown them to be no less movers of caloric, than of the fluid after which they have been named.

The Galvanic pair was first enlarged by me, to any considerable extent, in the instrument which I called the Calorimotor; agreeably to the views which I have taken, that caloric, always, in Galvanic processes, a collateral product of electricity, is, in apparatus of this kind, the predominant product.*

The following passage was published at the close of my first Memoir on the Galvanic Deflagrator:—

"I will take this opportunity of stating, that the heat evolved by one Galvanic pair, has been found, by the experiments which I instituted, to increase in quantity, but to diminish in intensity, as the size of the surfaces may be enlarged. A pair, containing about fifty square feet of each metal, will not fuse platina, nor deflagrate iron, however small may be the wire employed; for the heat produced in

* See Lecture on the Origin and Progress of Galvanism, or Voltaic Electricity, pages 40, 41.

metallic wires, is not improved by a reduction in their size beyond a certain point. Yet very small wires of the metals above mentioned, are easily fused, or deflagrated, by smaller pairs, which would have no perceptible influence on masses that might be sensibly heated by larger pairs. These characteristics were fully demonstrated, not only by my own apparatus, but by those constructed by Messrs. Wetherill and Peale, and which were larger, but less capable of exciting intense ignition. Mr. Peale's apparatus contained nearly seventy square feet—Mr. Wetherill's, nearly one hundred—in the form of concentric coils; yet neither could produce a heat above redness, on the smallest wires. At my suggestion, Mr. Peale separated the two surfaces in his coils into four alternating, constituting two Galvanic pairs in one recipient.—Iron wire was then easily burned, and platina fused, by it.—These facts, together with the incapacity of the calorific fluid, extricated by the calorimotor, to permeate charcoal—next to metals the best electrical conductor—must sanction the position I assigned to it, as being in the opposite extreme from the columns of De Luc and Zamboni. For, as in these, the phenomena are such as are characteristic of pure electricity, so in one very large Galvanic pair, they almost exclusively demonstrate the agency of pure caloric."

How far the phenomena of Electro-magnetism, since observed, tend to confirm, or enfeeble, the hypothesis above enunciated, will be considered, when on the subject of the last mentioned science.

I have constructed Calorimotors, in two forms—in the one, the surfaces are associated, so as to form one Galvanic pair—in the other, they form two pairs.*

ILLUSTRATIONS.

Calorimotors exhibited, and explained. Wires ignited.

* See Plate of the Calorimotor.

OF VOLTAIC SERIES.

ILLUSTRATIONS.

Voltaic Pile, as originally constructed, exemplified—also Couronne des Tasses.

Cruickshank's Galvanic Trough exhibited, in an improved form, which obviates the difficulty of suspending the action of the acid. Its effect on the animal frame, shown, or experienced. Water decomposed, and recomposed, by this apparatus.—Metals deflagrated by it. Mercury, placed in the circuit, while supported in a moistened cup of muriate of ammonia, swells up, retaining its metallic appearance, and losing its fluidity, as when it amalgamates with a metal. Being thrown into water, it regains its previous characteristics, while the presence of ammonia, in the water, is indicated by the proper tests.

Apparatus, employed by Sir Humphry Davy, exemplified, by three porcelain troughs, on each of which are suspended ten pairs of zinc and copper plates.

Apparatus of 280 pairs, exhibited—in which the cells are made, by cementing hollow glass parallelopipeds into a wooden tray, the tray being so situated, upon pivots, that the acid may be made to run into the cells, or out of them, by a partial rotation of the tray.

Apparatus, in which the cells are made by partitions of glass....and the Galvanic pairs, instead of being attached to beams, in order to be lifted out of the acid, are kept permanently in their cells, the acid being removed by a partial revolution of the trough upon pivots, when the action is to be suspended.

OF THE GALVANIC DEFLAGRATOR.

The motives, or views, which led to the construction of the Galvanic series, to which this name has been given—also the results which I obtained by it—are detailed, in a Memoir, and in a Letter to Professor Silliman, which will be found in the Appendix. I shall here confine myself, principally, to an explanation, and an experimental illustration, of its powers.

ILLUSTRATIONS.

Improved Galvanic Deflagrator of 300 pairs, exhibited, and explained. Deflagration, fusion, and volatilization of charcoal, anthracite, and plumbago, exhibited, agreeably to my observations, but more especially those of Professor Silliman:—Likewise of various metallic wires, of tin foil, tinsel, and mercury. Fusion and incorporation of iron and platina, under water. Hydrate of potash deflagrated upon charcoal, and upon a piece of silver coin.

Painful sensation experienced by the hands, when duly brought into the circuit.

ON GALVANIC THEORY.

According to Volta's theory, the contact of dissimilar metals, or their communication through perfect conductors—as for instance, metallic arches—is the source of Galvanic excitement: the solvent is instrumental, only, in transferring electricity from one pair of plates, in the series, to another.

Supposing this an adequate explanation, as applied to a *series*—applied to a single Galvanic pair, it is totally inadequate. When the different surfaces of a Galvanic pair, however large, are connected by a wire, however minute, no ignition is observable, till the plates are immersed in an acid. Ignition then ensues, if the size of the connecting wire be in due proportion to that of the plates. It must be evident, that if the ignition arises from an electrical discharge, from one of the heterogeneous metallic surfaces, to the other, simply in consequence of their communication through a perfect conductor, it ought to take place as soon as the communication is made.

Supposing that, in consequence of the metallic connexion, the zinc has become surcharged with electricity, at the expense of the copper, what additional effect can the acid, *merely acting as a conductor*, produce? It cannot be suspected of adding to the surcharge, by conveying an additional quantity of electricity from the copper to the zinc, as that

could not ignite the conjunctive wire; since, whatever passes through the fluid, does not go through the wire. Nor can it, for the same reason, be supposed to convey the excess in the zinc, back to the copper, in order to return to the zinc again; for, in this case, it would only renew a current, previously ascertained to be inadequate to produce ignition.

Volta's theory, is thus stated by Dr. Ure, in his Dictionary:—"Volta called his admirable invention an Electromotive apparatus, founding his theory of its operation upon the Franklinian idea of an electrical fluid, for which certain bodies have stronger attractions than others. He conceived that in his pile, the upper plate of zinc attracts the electricity from the copper, the copper from the water, the water again from the next plate of zinc, the next plate of zinc from the next plate of copper, and so on."

To this statement I subjoined, in the American edition, the following, as a note:—"If the zinc attract electricity from the copper, it has a stronger affinity for electricity. The water attracts electricity from the zinc; it has then a stronger affinity for it than zinc—and *a fortiori* stronger than copper, whose affinity is weaker than that of zinc. Copper cannot, then, attract electricity from water, by the premises."

The doctrine adopted by Wollaston, and others, that the power of a Voltaic series arises from an accumulation of electricity, evolved by chemical action of the solvent—being in quantity greater, and in intensity inferior, to mechanical electricity—is objectionable; because, the most ample accumulation of electricity, produced by other means, does not produce any similar results;*—because, the indications of electricity, during Galvanic ignition, are not commensurate with the effects;—because, heat is, at times, the predominant product, and is given off from a wire exposed in the circuit, for an unlimited time;—and because, by ascribing this heat to electricity, we do not in the slightest degree lessen the

* See Memoir on the Galvanic Deflagrator, Appendix, page 36.

difficulty, of accounting for the phenomena. That cáloric should be made to accumulate, by the contact of dissimilar metals, when acted on by solvents, is a fact difficult to believe—only, because there is nothing to support the conception, in our knowledge of the habitudes of that principle, as otherwise acquired; but, in our knowledge of the habitudes of electricity, there is not only a total deficiency of any thing in favour of its being susceptible of such accumulation and transfer, but much is known of it, which is irreconcilable with the idea, that it can thus act, or be acted upon. In its pure form, as evolved by mechanical means, it equalizes itself with the utmost rapidity, among metals, or amid moisture.

This objection to the idea, that electricity is the proximate cause of Galvanic ignition, derives support, from the successful construction of the deflagrator, where the pairs of the series *are not insulated* from each other.

It results, from my experiments, that, when the zinc plates, while thus uninsulated, are exposed at all their edges, the action in a numerous series is feeble—but is very powerful, when they are surrounded by copper, excepting at their upper and lower edges, as in the coils or copper cases of the deflagrator. It appears necessary, that the zinc of each Galvanic pair, should be precluded from direct communication, through the fluid, with any other metallic surface, excepting the copper of the succeeding pair, which surrounds it; but that the protection, thus required, is not of the nature which would be requisite, were electricity alone concerned, is evident—since it is afforded by copper, which, being a perfect conductor of electricity, could not, in the slightest degree, oppose the access or regress of that fluid, if unmodified by a union with other matter.

By the chemico-electric theory, the ignition produced by a single pair, is, the effect of a discharge of electricity, evolved by the action of the solvent. Yet the discharge is not in proportion to the activity, with which the solvent acts. The

effect, at the moment of immersion, is ten-fold greater, than afterwards, when the solution goes on with much greater rapidity.

I will here conclude my objections to the theories of others, and endeavour briefly to state my own views on the subject.

The power of Galvanic combination, to put into motion the imponderable, but material, causes of heat, light, and electricity, I conceive to be as occult, as the origin or nature of gravitation.

It seems to me, however, that, by Galvanic action—caloric, light, and electricity, are put into circulation, as collateral products; the proportion of the former, to the latter, being, (as already stated, page 41) as the extent of the metallic superficies subjected to the acid, to the number of pairs into which it may be divided;—that it is not improbable, that, by union with each other, these principles become more susceptible of transfer. Possibly, by such a union with each other, or with some unknown matter which regulates the Galvanic, and magnetic movements, they may escape our cognizance, while entering into, or passing out of, ponderable matter, in which chemical, or Galvanic changes, are taking place.

The effect of repose, upon Galvanic plates, in restoring their igniting powers, (whether connected or unconnected during the interval) argues in favour of a secret source, whence they renew their supply of igneous matter.

There are some other cases, in which the generation of caloric, and light, without some such occult causes, or properties, would be equally difficult to explain—especially, in that of the apparently unlimited extrication of heat by friction—the ignition of hydrogen by platina sponge—the explosion of oxygenated water with oxide of silver—the explosion of euchlorine, followed by expansion—the recomposition of water, by a spark from Voltaic wires, which, when immersed in it, cause its decomposition.

At all events, I conceive, that the three imponderable principles, of light, caloric, and electricity, must be considered as original and collateral products of Galvanic action; and that they are, most probably, carried by circulation, from the positive to the negative surface, through the fluid—and from negative to positive, through the metal;—and, if we suppose the electric fluid restrained from getting off through the solvent, in consequence of the incapacity of the caloric to be conducted through that fluid, otherwise than by circulation—the electric fluid, at the same time, subduing the propensity of the caloric to radiate—the explanation will appear more satisfactory.

Adopting this hypothesis, we may account for the intense heat evolved, when the circuit is completed by charcoal, or a small interval in the air. The non-conducting power of the coal, or the vacuity, tends to prevent the passage of the caloric, and light, by the conducting process, and to favour their escape by radiation—while the electricity, attracted by the opposite pole, and meeting no opposition from charcoal, or rarefied air, proceeds in the circuit, partially disburdened of its sluggish concomitants.

From the greater celerity with which electricity permeates metals, a similar evolution of caloric arises, on the passage of the Galvanic fluid through a fine wire; but, when the caloric becomes evanescent, as in the column of De Luc, charcoal is no longer ignited—because, there is no caloric to evolve;—and, on the other hand, when the electricity verges towards its minimum of intensity, it has no longer force to project the caloric, into a substance, so unfavourable to its conveyance. Hence, by a single Galvanic pair, charcoal cannot be ignited.

OF THE TORPEDO, GYMNOTUS, AND SILURUS ELECTRICUS.

Before concluding, I will say something of the Torpedo, the Gymnotus, and Silurus Electricus.

The benumbing power of the Torpedo, was noticed by the ancients—and continued to excite the wonder of modern naturalists. Within the last century, two other fishes, the Gymnotus, and Silurus, were discovered to possess the power of giving a shock to other animals, so severe, as to occasion death. The Gymnotus, especially, is alleged, at times to be large enough, and to possess power, to destroy human life. The organs of these animals, are said to consist of a prodigious number of cells, arranged in columns. According to Wilkinson, there are as many as one hundred and fifty thousand, in one fish. In the Torpedo, the cells are, in breadth, only about one-tenth of an inch. A slight spark was produced, when a discharge by a Gymnotus was made to traverse a kerf, made by a knife in a slip of tin foil.

These facts, must intimately associate our progress, in Physiology and Galvanism; and may lead us to hope, that Galvanic inquiries, already so serviceable to Chemistry, may, ere long, render important services, in Physiological investigation.

ON ELECTRO-MAGNETISM.*

RESPECTING this new science, it will be in my power only, to present a few general ideas, and illustrate them by a few experiments.

It had long been observed, that there were striking analogies, as well as discordancies, between the characteristics of Electricity and Magnetism. The similar poles of magnets, freely suspended, were observed to recede from each other, and dissimilar poles to approach each other, in a mode, quite analogous to the separation, or approximation, of substances, similarly, or dissimilarly electrified.

It had also been observed, that iron, in the vicinity of lightning rods, or otherwise exposed to lightning, had, in some instances, been rendered magnetic.

So far, then, an analogy might be observed, between electrical and magnetic phenomena; but, the magnetic repulsions and attractions, were observed, under circumstances as unfavourable to the existence of the opposite electricities, as possible. The magnetic needle is a perfect conductor; and of course there could be no permanent existence of opposite electrical excitement, at its extremities. Moreover, neither

* I have adopted the name given to this science, in obedience to usage; though I conceive, that the term *Galvano-Magnetism*, would be more appropriate.

pole of a magnet was more susceptible of being attracted by electrified bodies, than any other metallic wire, similarly suspended; nor did either of the electricities affect one pole, more than the other.

The poles of the Voltaic apparatus, were found to be perfectly indifferent to those of a magnet, when it was presented to them, during that interruption of the circuit, which was deemed necessary to the production of electrical excitement; since making a communication, by an adequate conductor, between bodies differently electrified, had been supposed to neutralize all electric power. Under these circumstances, then, it never occurred to any one, that the magnetic poles could be influenced by electricity, whether Galvanic, or mechanical, till Professor Oersted, in the winter of 1819, happily placed a magnetic needle, near a wire, forming a connexion between the poles of a Voltaic apparatus. It was found to have a tendency to arrange itself at right angles to the wire—its poles always taking a certain posture, relatively to the Galvanic current in the excited wire.

Supposing the Galvanic fluid to be passing through a wire, from the positive to the negative pole, of the apparatus—and that the wire is placed over a magnetic needle, so that the current may flow from the south to the north, the north pole of the needle will point west—but will point east, if the wire be below the needle. The direction of the Galvanic current being reversed, the north pole of the needle will point in directions, opposite to those above mentioned, when similarly situated with respect to the wire. If the needle be suspended, like a dipping needle, and the wire be placed parallel to it, on the east side, in the same horizontal plane, the current being still from south to north, as before—the north pole will point upwards. Circumstances otherwise remaining the same, if the wire be shifted to the west side of the needle, the north pole of the needle will point downwards.

An idea of the various positions of the needle, accordingly as placed above, below, on either side of the wire, or in any

intermediate station, may be formed, from those of a ship, in sailing due east round the world; supposing her bow to answer to the north pole of the magnetic needle—her stern, to the south pole—and the axis of the globe, to the wire.—Supposing the poles of the earth to be reversed, in their astronomical relation, so that the north star should be over the part of the globe now called the south pole—the same changes would take place, in the various situations of the ship, relatively to an imaginary line through the earth's axis, as would be produced in those of the needle, relatively to the excited wire, should the direction of the Galvanic current through it, be reversed, so as to flow from north to south, instead of moving as before proposed.

By Mr. Ampere, a French philosopher of celebrity, it was ascertained, (not long after Oersted's discovery) that wires, completing the circuit of different Galvanic batteries, would attract and repel each other, but not in a mode analogous to electrical attractions—since it was between the terminations, similarly excited, that the attraction was observed, while the repulsion took place between terminations dissimilarly excited. Electrical indications are obtained, only, when the poles of the generating apparatus are unconnected; those afforded by the Galvanized wires, were the consequence of their connecting the poles of the Galvanic apparatus.

Not long after these observations, of Ampere, it was remarked, by Arago, Davy, and others, that the uniting wire was capable, like a magnet, of attracting iron filings—but incapable of attracting copper or brass filings, or sawdust.—Also, that a needle, placed transversely to the Galvanic wire, became permanently magnetic. This power, of imparting the magnetic property, was prodigiously increased, by forming the wire into spirals.

The polarity, given to the needle, varied, accordingly as the spiral was wound to the right, or to the left—or, the spiral remaining the same, the polarity varied with the direction of the current.

Assuming, that the current proceeds in the wire, from the positive to the negative pole, of the Galvanic battery, the spiral being wound to the right—the end of the needle pointing in the same direction, as that in which the stream flows, would acquire a north polarity—the other end acquiring the south polarity; but, reversing the spiral, the effect on the needle would be reversed.

When the same wire was made to constitute, at the same time, a right and a left spiral, a needle being placed within each, so that the whole might be simultaneously subjected to the one Galvanic current—the ends of the needles which were nearest each other, and those farthest from each other, were similarly polarized, instead of having alternately a north, and a south pole, as when the spirals were alike.

In a needle, sufficiently long to extend through different spirals, in one Galvanized wire, the parts severally comprised within the different spirals, were found each to have two appropriate poles.

A needle was magnetized, when placed on the outside of a spiral, parallel to the axis—but the polarity was the opposite of that imparted to it, when placed within the same spiral.

Mr. Ampere next discovered, that, when a wire is formed into a circle, having bent terminations in a common vertical line, so that the whole may turn as if supported upon a common axis, the circle assumes a situation, at right angles to the magnetic meridian—and so that the current, from positive to negative, passes downwards on the eastern side, and upwards on the west.

Magnetism was, subsequently, produced by discharges of mechanical electricity, in the same way as by Galvanic discharges, but with less facility.

Mr. Ampere, afterwards, most ingeniously, caused the ends of a wire forming a spiral, to return through the axis of the spiral, without touching it; and, passing them out of the spiral, one on one side, the other on the other side, they were

made to form an axis, on which the whole might revolve.—The different ends of the wire, thus arranged, being made duly to communicate with a Galvanic battery, the spiral was acted upon by a magnet, as one magnet is actuated by another.

A more extraordinary instance of reaction, between magnets, and Galvanic wires, was adduced, by Mr. Faraday, Assistant Lecturer at the Royal Institution.

A magnet being attached to the centre, in the bottom of a cup of mercury, by a silk thread; a wire is fixed over it, vertically, so as just to enter the mercury for a small depth. The metallic support of the wire, is connected with one pole of a Galvanic battery—the mercury with another. In this case, the upper end of the magnet, while swimming in the mercury, revolves, from right to left, or from left to right, about the wire, accordingly as the poles of the magnet, or the connexions with the Galvanic apparatus, may be exchanged. If, on the other hand, the magnet be made immoveable, while the vertical wire is upon a universal joint—the wire will revolve about the magnet, and be liable to change its direction, in the same way, as the moveable magnet was actuated, with respect to the wire.

If a wire be suspended upon a metallic hinge, between the poles of a magnet (in the horse-shoe form) while lying in mercury, the mercury and the wire being placed in the Galvanic circuit, the wire will undergo an alternate motion,—being thrown out of the mercury, whenever it completes the circuit by touching it, in a line parallel to the sides of the magnet,—and, in opposite directions, accordingly as the poles of the magnet, or the connexions, are altered.

If a wheel, with an edge cut into teeth, like those of a large saw, be substituted for the wire in the last mentioned apparatus, it will revolve rapidly, and in opposite directions, accordingly as situated, with respect to the Galvanic current, and the poles of the magnet.

If two concentric cylinders of copper, be united, so as to leave an interstice between them, closed at bottom; and if, between these, a cylinder of zinc be suspended, so that the whole may be supported concentrically, by pivots, upon one of the poles of a magnet—on pouring acid into the interstice, a rotation of the cylinders, one within the other, will ensue, the copper moving one way, the zinc the other; and the motion will be reversed, when the suspension is shifted from one pole of the magnet to the other.

OF THERMO-MAGNETIC, OR THERMO-ELECTRIC, DISCOVERIES.

The next important step, in magnetical investigation, was, the discovery, by Oersted, Fourier, Cummins, Sturgeon, Trail, and others, of a mode of influencing the magnetic needle, by heterogeneous metals united by soldering, or held together by wire, and kept at different temperatures.—When bars of antimony, and bismuth, were so soldered together as to form the alternate sides of parallelograms—or, when copper, in an arch, was, at its extremities, fastened to a bar of antimony, by wire, a diversity of temperature being produced at the junctures,—a delicate magnetic needle was subjected to changes, analogous to those produced by Galvanized wires. When bows of platina wire, were connected with silver wire—the whole supported, on a magnet, by a pivot, and the circuit completed through the magnet, by the application of a lamp at the outer extremities of the arch—a revolution was produced, in a mode, analogous to that of the rotatory cylinders, and the revolving wires of Faraday, Ampere, Barlow, Marsh, and others.

EXPERIMENTAL ILLUSTRATIONS

OF

ELECTRO-MAGNETISM.

Magnetic influence of wires, Galvanized by large, and by small calorimotors, on needles of various sizes.

Magnetic needles, presented to the Galvanic poles, or rods proceeding from them, while the circuit is incomplete, are uninfluenced; but, when in the neighbourhood of the completed circuit, are much agitated.

Two magnetic needles, each fourteen inches in length, exhibited;—the north pole, of each, duly marked. When the Galvanic current is made to flow through a wire, from south to north, the north pole of one of the needles placed below it, points west:—the north pole of the other needle, being at the same time above it, points east. One of the needles being to the westward, the other to the eastward of the current, in the north pole of the western needle a tendency to rise is observed, while the north pole of the eastern needle displays the opposite tendency. Inverting the direction of the current, or exchanging the position of the needles, causes corresponding changes of the directions, in which the needles point.

Galvanized wires, attached to different calorimotors, exhibited, and their reaction shown.

Attraction of the uniting wire, for iron filings—and its incapacity to attract other substances,—demonstrated.

REMARKS.

As the movements of the south and north poles are, in the same needle, necessarily opposite, I have spoken only of the direction of the north pole.

Independently of the influence of gravitation, or the magnetism of the earth, the positions assumed by magnetic needles, relatively to a Galvanic current sufficiently near them, are those of tangents to circles, in the axes of which the current flows. Or, supposing an observer to look along the wire, in the direction of the current—and supposing a radius, proceeding from the wire, to meet the needle in the middle—the needle will be at right angles to, and in the same plane with, that radius. At the same time, the north pole will point in a direction, which, if pursued, would be productive of a revolution, in the direction called right, when described with respect to a spiral, or screw—being analogous to that given to the hands of clocks and watches.

To present the idea in another way.—Let the student look perpendicularly on the pivot of his watch: let him suppose an arrow representing the needle, and the direction in which its north pole points, to be attached to the end of one of the hands, and at right angles to it. If a Galvanic current be supposed to flow through a wire passing from the student's eye, through the pivot, the situations of the arrow, during one revolution of the hand, will give him an idea of all the positions which the needle, when carried round the wire, would assume, relatively to the Galvanic current.

Supposing the current to be reversed, to flow towards the eye—it is only necessary to imagine the movement of the hand reversed, and the arrow head pointing in the opposite direction, to give an idea of the positions, and the directions, in which the needle would then be found, if carried round the Galvanized wire.

Polarization of needles, by exposure in Galvanic spirals. Difference of the polarity produced, accordingly as the spirals are right, or left.

Poles of large needles, above described, reversed.

Effect of different spirals, formed in the same wire, on needles severally placed in them.....and on one needle extending into spirals, alternately right and left, in the same wire.

Effect of a Galvanized spiral, on a needle placed outside of it, parallel to its axis.

Large iron bar, magnetized by a transient exposure, in a spiral, Galvanized by a large calorimotor.

Wire, formed into a circle, with its terminations bent into a common vertical line:—effect of the Galvanic current, on such a wire, shown.

Exhibition of an oblong spiral of wire, the terminations of which, after being returned to the centre along the axis, are passed out of the spiral, above and below it, so that they severally communicate with different Galvanic poles, and yet permit the spiral to traverse like a compass needle. A magnet being presented to the spiral, thus described, while in the circuit, it is attracted, and repelled, as if it were a magnet.

Alternate, or rotatory movements, produced in wires, and wheels, Galvanized, while in the vicinity of a magnet.

Rotatory cylinders, of Ampere and Marsh.

Rotation of a thermo-magnetic apparatus, Galvanized by heat, about the poles of a magnet, on which it is supported, by a pivot.

ON ELECTRO-MAGNETIC THEORIES.

So uncommon is the sagacity displayed by Professor Oersted, in his experimental investigations, that his theoretic opinions must be received with great deference, even by those to whom they are unintelligible, or unsatisfactory. I shall therefore quote, at the end of the Appendix, his theoretic doctrine, as briefly enunciated in his first paper. For similar reasons, I shall add to the Appendix, a sketch of Mr. Ampere's Electro-magnetic hypothesis, as it has been given by an anonymous writer, in the Annals of Philosophy, whom I suspect to be Dr. Thomson.

Mr. Ampere, as an experimenter, is not inferior, in ability, to Professor Oersted. The author of the sketch which will be quoted, in the Appendix, introduces it with the following remarks :—

"*Of all the theoretic views that have been given of Electro-magnetical phenomena, those by M. Ampere are the most extensive and precise, and have been tested by the application of facts and calculation very far beyond any of the rest. Indeed it is these alone among all those that have been given to the public, which deserve, if any do, the title of A Theory.*"

OF PROFESSOR OERSTED'S THEORY.

Professor Oersted conceives, that there are two different electric fluids, evolved by Galvanic action, which have a "*conflict,*" on meeting, in the wire which unites the Gal-

vanic poles—and that the magnetic influence is due to this conflict, which, to use his own words, "*is not confined to the conductor, but is dispersed widely in the circumjacent space.*"

If the "conflict" extends into the circumjacent space, the combatants must be there to support it. The language of the distinguished Professor, gives a materiality to the conflict itself; so that it may be inferred to be his meaning, that, while the electricities are within the wire, their conflict extends "widely" beyond its circumference.

If it be alleged, that he intended to convey the idea, that the two electricities, in a state of contention, expand themselves into the circumjacent space, as far as the magnetic power prevails—it would follow, that the current, which passes from one pole of a Galvanic battery, to another, must be several feet in diameter. How an electrical current, so diffuse, can be sufficiently concentrated, to ignite a wire, is to me unintelligible.

A conflict between two substances, can, in my mind, awaken no other idea, than that of an intense reaction between them. The most intense reaction of this kind, cannot be productive of any effect upon other matter, which is not made a party to it. If any neighbouring body be affected, it must be by a conflict of one, or both, of the electricities, with that body—not by any conflict of the electricities with each other. During the conflict of compounds, matter may be liberated, which may have an influence on the adjoining bodies; but, Professor Oersted's language, respecting the electrical conflict, precludes the idea, that any matter is concerned, besides the two electricities.

The author of the hypothesis, infers, "*that this conflict performs circles—for without this condition, it seems impossible that one part of the uniting wire, when placed below the needle, should drive it towards the east, and when placed above it, to the west.*"

And again, in the same paragraph, he observes:—"*Besides, a motion in circles, together with a progressive motion, ought to form a conchoidal or spiral line.*"

As, in the next paragraph, the celebrated author informs us, "*that negative electricity moves in a spiral line, but towards the right*"—and we are to "*ascribe to positive electricity a contrary motion:*" it seems to me, that the conflict can, consistently with his premises, undergo no movement, unless the circuit in which it takes place, be moved—since the only alleged cause of the conflict, is, the collision, in the circuit, of two electric fluids, moving in different spirals, and in opposite directions.

It is now well known, that every part of a Galvanic circuit is endowed with the magnetic power. Of course, the conflict which creates this power, must be supposed to exist throughout the whole circuit, with a greater or less intensity in the different parts, according to the degree of their conducting or electromotive power—and, being produced by opposite and equivalent spiral movements, cannot itself have any motion.

Professor Oersted, in concluding, alleges himself to have "*demonstrated, that heat and light consist of the conflict of the two electricities.*"

The size of the sun, to the earth, is as a million to one—and, in light and heat, its superiority is still greater. Consistently with this allegation of Professor Oersted, there must be an electrical conflict in the sun, almost infinitely great, when compared with the aggregate of all that can exist in this planet. Yet, while ascribing the magnetic power, of Galvanism, to a conflict of the electricities, the learned theorist does not make the slightest allusion to solar influence.

OF M. AMPERE'S THEORY.

Mr. Ampere's theory, no less than that of Professor Oersted, being founded on the postulate, that there are two electric fluids, I refer to an Essay, subjoined in the Appendix, for my objections to that doctrine.

In no instance do I find the hypothesis, founded on the alleged existence of two electric fluids, more incomprehensible, than when applied to the case of a wire, excited by uniting the Galvanic poles. According to the hypothesis in question, the excitement is due to currents, of the different electricities, entering the wire from the poles, at which they respectively accumulate. One of two consequences must ensue, under these circumstances: either a combination between the electricities must take place, on their meeting—or, they must pass each other.

As opposite electricities, are alleged to exercise an intense attraction, it is inconceivable, that, either by a pressure in one direction, or an attraction in the other, they should pass each other, instantaneously, in a wire several hundred feet long. If they combine, what becomes of the compound, which they form?

It has been mentioned, that wires, Galvanized by different batteries, were found to attract each other, when similarly excited, and to repel each other, when dissimilarly excited. In other words—when they are placed side by side, so that the Galvanic currents, to which they are respectively subjected, may flow through them in the same direction, they attract each other—but, are repellent of each other, when, in this respect, their situations are reversed, so that the current in one, moves oppositely to that in the other.

The discordancy of these phenomena, with those usually resulting from electrical excitement, is, by Mr. Ampere, ascribed to the difference between electricity, when in mo-

tion, and when in a state of tension. I am ignorant of any analogy, in nature, which would justify the idea, that the attractive, or repulsive energies, of matter, can be reversed, merely by a change, from motion to rest.

Pursuing the idea, that magnetic phenomena are due to electricity, in motion—Mr. Ampere supposes curvilinear currents to exist in or about all magnetic substances, and of course in or about all magnets, and the earth itself as one of them. It is the property, of inducing, or influencing, these electrical currents, which is imparted to a steel bar, when it is converted into a magnet. That the particles of a motionless solid, can produce movements in other matter, for an unlimited time, appears to me incomprehensible. I deem it more probable, that the magnetic properties arise from the presence of a fluid, in which electricity exists, as an ingredient; though, in consequence of being in union with other matter, it is no less latent, as respects electrometrical indications, than caloric is, when in combination, with respect to those of the thermometer. That a current of electricity should be made to act, at the distance of many feet, on a magnetic needle, and yet should not affect the most delicate electrometer, appears to me inexplicable, unless some cause be assigned for this latency, in the one way, and this activity, in the other.

The mode in which Galvanic plates recover their supply of the calorific principle, after a short repose, and the unlimited extent to which heat is given off by friction, leads me to suspect, that those principles have some unknown mode of becoming latent.

In 1819, while operating with a small compound coil of copper and zinc, such as was afterwards used for the deflagrator, I observed, that a fine wire, connecting the metals, might be made white hot, on their first immersion in the acid, but soon cooled, if they were kept in it for any considerable time—nor would another immersion renew the ignition, unless they were allowed to remain out of the acid for

about a minute. After this time had elapsed, on immersing the coil, the wire would be ignited, but not so intensely, as when a longer period intervened, between the immersions—as it made no difference, whether the uniting wire was removed, or remained in its place, during the repose of the surfaces. It follows, that the ignition did not result from a restoration of an equilibrium, between the surfaces, with respect to the igniting principle, during their repose—which had been disturbed, during their immersion. Hence it occurred to me, that the recovery of power must be derived from the medium around—and that it was possible, that the principles producing it, existed in that medium, and were communicated to the Galvanic plates in a latent form. This idea seems to have received some support, from Oersted's discovery.

I have since ascertained, that the accumulation of igniting power, in Galvanic plates, takes place during repose, when gaseous oxygen, or chlorine, are present—but not in hydrogen, carbonic acid, or nitrogen.

May we not venture to surmise, that oxygen gas, during respiration, is the vehicle of some unknown imponderable matter, or combination of such matter, which is necessary to life—and that it is the deprivation of this matter, not oxygen, that causes life to cease with respiration? It is now generally admitted, that the support of animal heat, cannot be ascribed, more than partially, to the respiratory process—and, at all events, the death which follows the want of air, is too sudden, to be the consequence of any concomitant deficiency in the supply of caloric.

Ponderable oxygen abounds in our food, and in our drink. Fishes live in water, of which it is the principal constituent. It cannot therefore be supposed, that a supply, either of the caloric, or the ponderable base of oxygen gas, is the object of the gills in them, or of the lungs in breathing animals.

Will not these considerations, afford some justification for a conjecture, that this gas may be the vehicle of some occult

imponderable matter, which, while it is the source of vital, and of Galvanic action, may also be an agent in the production of electro-magnetic phenomena? I am, however, decidedly of opinion, that human reason, and knowledge, are, as yet, incompetent to suggest any satisfactory theories of Electro-magnetism, or Galvanism.

OF THE INFLUENCE OF ELECTRO-MAGNETIC DISCOVERIES, ON GALVANIC THEORY.

It does not appear to me, that the production of electro-magnetic phenomena, both by Galvanic, and by electrical discharges, disproves my opinion, that caloric, and electricity, are connate and co-ordinate products, of Galvanic action.

As ignition is producible, by either discharge, whether electric or Galvanic, the fluid of heat, no less than the electric fluid, may, in both cases, be concerned; and it is yet to be shown, that magnetic phenomena are ever due, to the unalloyed agency of electricity.

It is true, that magnetism has been imparted, by discharges of mechanical electricity, without any ostensible agency of caloric; but, it is equally true, that magnetic movements have been produced also, by the application of heat, unaccompanied by any ostensible agency of the electric fluid:—and it seems as rational to suppose, that caloric and electricity are associated, in the first instance, as in the last.

Those who consider electricity, varying in quantity, and intensity, as the common cause of electrical and Galvanic ignition, and of thermo-magnetic phenomena, must suppose, that this principle, and caloric, are capable of a reciprocal action. In the first case, caloric is evolved by electric action; in the last, electric currents are produced by calorific repulsion. Hence, as action and reaction, are equal and con-

trary, I deem it rational to suppose each to be the prime agent, in different cases—but, that both are associated in all, where deflagration, or magnetic phenomena, are induced.

I will here conclude, with the admission, that, theorizing on these subjects, is of more use as an intellectual exercise—or, from its associating the phenomena in general views, and leading us to scrutinize them more attentively, and thus to remember them better, than from any probability of our arriving at incontrovertible conclusions.

NOTICE TO THE STUDENTS.

Although I have deemed it expedient, to put it into the power of my Pupils to acquire some knowledge of the science of Electro-magnetism, I wish it to be understood, that it is not my intention to propose any questions, respecting it, at the examination for Degrees.

APPENDIX.

APPENDIX.

ESSAY,

ON THE QUESTION, WHETHER HEAT CAN BE ASCRIBED TO MOTION.

In two Memoirs, published in Professor Silliman's Journal of Science and the Arts, I have endeavoured to show, that caloric and the electric fluid are collateral agents in galvanism —the ratio of the former to the latter, in quantity, being as the extent of the operating superficies, to the number of pairs into which it may be divided.

It was of course assumed, in those publications, that the causes of heat and electricity, are material. Although this view of the source of calorific repulsion, is taken by a great majority of chemists, it has been combated, both by Rumford, and Davy: the former, famous for his ingenious, instructive, and laborious experiments—and the latter, distinguished by the most splendid discoveries. With the utmost deference for the authority of these great men—especially the latter—I offer the following remarks, made in answer to his hypothetical views, which I shall here quote from his Elements, in order to introduce the subject more intelligibly.

"It seems possible," says the illustrious author, "to account for all the phenomena of heat, if it be supposed, that in solids the particles are in a constant state of vibratory motion, the particles of the hottest bodies moving with the greatest velocity, and through the greatest space—that, in fluids, and elastic fluids, besides the vibratory motion, which must be conceived greatest in the last, the particles have a motion round their own axes, with different velocities, the particles of elastic fluids moving with the greatest quickness—and that, in ethereal substances, the particles move round their own axes, and separate from each other, penetrating in right lines through space. Temperature may be conceived to depend upon the velocities of the vibrations; increase of capacity on the motion, being performed in greater space; and the diminution of temperature, during the conversion of solids into fluids or gases, may be explained on the idea of the loss of vibratory motion, in consequence of the revolution of particles round their axes, at the moment when the body becomes liquid or aëriform—or from the loss of rapidity of vibration, in consequence of the motion of the particles through greater space.

"If a specific fluid of heat be admitted, it must be supposed liable to most of the affections which the particles of common matter are assumed to possess, to account for the phenomena: such as losing its motion when combining with bodies—producing motion, when transmitted from one body to another—and gaining projectile motion, when passing into free space; so that many hypotheses must be adopted to account for its mode of agency, which renders this view of the subject less simple than the other. Very delicate experiments have been made, which show that bodies, when heated, do not increase in weight. This, as far as it goes, is an evidence against a specific subtile elastic fluid, producing the calorific expansion; but it cannot be considered as decisive, on account of the imperfection of our instruments. A cubical inch of inflammable air, requires a good balance to ascertain that it has any sensible

weight—and a substance bearing the same relation to this, that this bears to platinum, could not perhaps be weighed by any method in our possession."

These suggestions of Sir H. Davy, are, to me, unsatisfactory.

It is fully established in Mechanics, that when a body in motion is blended with, and thus made to communicate motion to, another body, previously at rest, or moving slower, the velocity of the compound mass, after the impact, will be found, by multiplying the weight of each body, by its velocity, and dividing the sum of the products, by the aggregate weight of both bodies. Of course it will be more than a mean, or less than a mean, accordingly as the quicker body was lighter or heavier than the other.

Now, according to Sir Humphry Davy, the particles of substances which are unequally heated, are moving with unequal degrees of velocity. Of course, when they are reduced by contact to a common temperature, the heat, or what is the same, (in his view) the velocity of the movements of their particles, ought to be found, by multiplying the heat of each by its weight, and dividing the sum of the product by the aggregate weight. Hence if equal weights of matter be mixed, the temperature ought to be a mean—and if equal bulks, it ought to be as much nearer the previous temperature of the heavier substance, as the weight of the latter is greater; but the opposite is, in most instances, true. When equiponderant quantities of mercury and water are mixed, at different temperatures, the result is such as might be expected, were the water twenty-eight times heavier; so much nearer to the previous temperature of the water, is that of the mixture.

It may be said, that this motion is not measurable upon mechanical principles. How, then, I ask, does it produce mechanical effects? These must be produced by the force of the vibrations, which are, by the hypothesis, mechanical: for whatever laws hold good, in relation to moving matter in mass, must operate in regard to each particle of that matter; the effect of the former, can only be a multiple of that of the

latter. Indeed, one of Sir Humphry Davy's reasons, for attributing heat to corpuscular vibration, is, that mechanical attrition generates it. Surely, then, a motion, produced by mechanical means, and which produces mechanical effects, may be estimated on mechanical principles.

In the case cited above, the power of reciprocal communication of heat in two fluids, is shown to be inconsistent with the views of this ingenious theorist. If we compare the same power in solids, the result will be equally objectionable.—Thus, the heating power of glass being 443, that of an equal bulk of lead will be 487, though so many times heavier; and if equal weights be compared, the effect of the glass, will be four times greater than that of the lead.

If it be said, that the movements of the denser matter are made in less space, and therefore require less motion—I answer, that if they be made with equal velocity, they must go through equal space in the same time, their alternations being more frequent. And if they be not made with the same velocity, they could not communicate to matter of a lighter kind, a heat equally great—since, agreeably to experience, no superiority of weight will enable a body, acting directly on another, to produce in it a motion quicker than its own.

Consistently with this doctrine, the particles of an aëriform fluid, when they oppose a mechanical resistance, do it by aid of a certain movement, which causes them effectively to occupy a greater space than when at rest. It is true, a body, by moving backwards and forwards, may keep off other bodies from the space in which it moves. Thus, let a weight be partially counterbalanced, by means of a scale beam, so that, if left to itself, it would descend gently. Place exactly under it, another equally solid mass, on which the weight would fall, if unobstructed. If, between the two bodies, thus situated, a third be caused to undergo an alternate motion, it may keep the upper weight from descending, provided the force with which the latter descends, be no greater than that of the movement in the interposed mass, and the latter acts with such celerity, that, between each stroke, the time be too

small for the weight to move any sensible distance. Here, then, we have a case analogous to that supposed—in which, the alternate movements or vibrations of matter, enable it to preserve to itself a greater space, in opposition to a force impressed; and it must be evident, that lengthening or shortening the extent of the vibrations of the interposed body, provided they are made in the same time, will increase or diminish the space apparently occupied by it, as the volume of substances is affected by an increase or reduction of heat. It ought, however, to be recollected, that, in the case we have imagined, there is a constant expenditure of momentum, to compensate for that generated in the weight by gravity, during each vibration. In the vibrations conceived to constitute heat, there is no generating power to make up for this loss. A body preserves the expansion, communicated by heat in vacuo, where, insulated from all other matter, the only momentum, by which the vibrations of its particles can be supported, must have been received before its being thus situated. If we pour mercury into a glass tube shaped like a shepherd's crook, the hook being downwards, and the orifice closed, the included air will prevent the mercury from occupying a portion of the tube. In this case, according to the hypothesis in question, the entrance of the mercury into the space which the air occupies, is resisted by a series of impalpable gyratory movements; so that the collision of the aërial particles against each other, causes each to occupy a larger share of space, in the manner above illustrated, by the descending weight and interposed body. The analogy will be greater, if we suppose a row of interposed bodies, alternately striking against each other, and the descending weight; or we may imagine a vibration in all the particles of the interposed mass, equal, in aggregate extent and force, to that of the whole, when performing a common movement. If the aggregate force of the vibrations made by the particles, be equivalent to that which, when performed in mass, would be necessary to preserve a certain space—it may be supposed productive of a substance like the air, by which the mercury

is resisted. But, in such rare media, whence can momentum be derived, adequate to resist the pressure of a fluid so heavy as mercury, which, in this case, performs a part similar to that of the weight, cited for the purpose of illustration?—If it be said, that, the mercury and glass being at the same temperature as the air, the particles of these substances vibrate in a manner to sustain the aërial pulsations; I ask, when the experiment is tried in an exhausted receiver, how is momentum to be supplied to the mercury and glass? There is no small difficulty in imagining, that, under the most favourable circumstances, a species of motion, existing, according to the hypothesis, as the cause of expansion in a heated solid, should cause a motion productive of fluidity or vaporization—as when, by means of a hot iron, we convert ice into water, and water into vapour.

Is it not inconceivable, that the iron boiler of a steam engine should impart, to the particles of water, a motion, so different from any which it can itself possess, and, at the same time, capable of such wonderful effects, as are produced by the agency of steam? In particles, whose weight does not exceed a few ounces, can sufficient momentum be accumulated, to move as many tons?

There appears to me another very serious obstacle to this explanation of the nature of heat. How are we to account for its radiation in vacuo, which the distinguished advocate of the hypothesis has himself shown to ensue? There can be no motion without matter. To surmount this difficulty, recourse is had to a suggestion of Newton, that the calorific vibrations of matter may send off radiant particles, which lose their own momentum in communicating vibrations to bodies remote from those, whence they emanate. Thus, according to Sir Humphry, there is radiant matter producing heat, and radiant matter producing light. Now, the only serious objection made by him, to the doctrine which considers heat as material, will apply equally against the existence of material calorific emanations. That the cannon, heated by friction in the noted experiment of Rumford, would have ra-

diated as well, as if heated in any other way, there can, I think, be no doubt; and as well in vacuo, as the heat excited by Sir Humphry in a similar situation. That its emission in this way, would have been as inexhaustible as by the conducting process, cannot be questioned. Why, then, is it not as easy, to have an inexhaustible supply of heat, as a material substance, as to have an inexhaustible supply of radiant matter, communicating the vibrations, in which he represents heat to consist?

We see the same matter, at different times, rendered self-attractive, or self-repellent; now cohering in the solid form with great tenacity—and now flying apart with explosive violence, in the state of vapour. Hence the existence, in nature, of two opposite kinds of reaction, between particles, is self-evident. There can be no property without matter, in which it may be inherent. Nothing, can have no property. The question then is, whether these opposite properties can belong to the same particles. Is it not evident, that the same particles cannot, at the same time, be self-repellent, and self-attractive? Suppose them to be so—one of the two properties must predominate; and in that case, we should not perceive the existence of the other. It would be useless, and the particles would, in effect, possess the predominant property alone, whether attraction or repulsion. If the properties were equal in power, they would annihilate each other, and the matter would be, as if void of either property. There must, therefore, be a matter, in which the self-repellent power resides, as well as matter in which attraction resides.

There must, also, be as many kinds of matter, as there are kinds of repulsion—of which, the affinities, means of production, or laws of communication, are different. Hence I do firmly believe in the existence of material fluids, severally producing the phenomena of heat, light, and electricity.—Substances, endowed with attraction, make themselves known to us, by that species of this power, which we call gravitation, by which they are drawn towards the earth, and are

therefore heavy and ponderable; by their resistance to our bodies, producing the sensation of feeling, or touch—and by the vibrations or movements which they excite in other matter, affecting the ear with sounds, and the eye by a modified reflection of light. Where we perceive none of these usual concomitants of matter, we are prone to infer its absence.—Hence ignorant people have no idea of air, except in the state of wind; and, when even in a quiescent state, designate it by this word. But that particles, endowed with self-repellent power, should not be thus perceived, is far from being a reason for doubting their existence. A very slight attention to their qualities, will make it evident, that they could not produce any of the effects, by which the existence of matter, in its ordinary form, is recognized. Repelling each other, they cannot resist penetration: possessing no sensible weight, the greatest velocity can endow them with no perceptible momentum. When in combination, *they* are not perceived, but the *bodies* with which they combine; and it is only by the changes thus produced, or their influence upon our nerves, that it were reasonable to expect any indication of their existence.

ESSAY

ON THE GALES EXPERIENCED IN THE ATLANTIC STATES OF NORTH AMERICA.*

Of the gales experienced in the Atlantic States of North America, those from the north-east, and north-west, are by far the most influential: the one, remarkable for its dryness—the other, for its humidity. During a north-western gale, the sky, unless at its commencement, is always peculiarly clear, and not only water, but ice, evaporates rapidly. A north-east wind, when it approaches to the nature of a durable gale, is always accompanied by clouds, and usually by rain or snow. The object of the following essay, is to account for this striking diversity of character.

When, by a rise of temperature, the lower portions of a non-elastic fluid are rendered lighter, than those which are above them, an exchange of position must ensue. The particles which were coldest at first, after their descent, becoming the warmest, resume their previous elevation—from which, they are again displaced, by warmer particles. Thus, the temperatures reversing the situations, and the situations reversing the temperatures, a circulation is kept up, tending to restore the equilibrium.

Precisely similar would be the case with our atmosphere, were it not an elastic fluid, and dependent for its density, on

* Read May 14th, 1822, before the Academy of Natural Sciences of Philadelphia, in whose Journal it was first published.

pressure, as well as on heat. Its temperature would be much more uniform than at present—and all its variations would be gradual. An interchange of position would incessantly take place, between the colder air of the upper regions, and the warmer, and of course lighter, air, near the earth's surface, where there is the most copious evolution of solar heat. Currents would incessantly set from the poles to the equator below, and from the equator to the poles above. Such currents would constitute our only winds, unless where mountains might produce some deviations. Violent gales, squalls, or tornadoes, would never ensue. Gentler movements would anticipate them. But the actual character of the air, with respect to elasticity, is the opposite of that which we have supposed. It is perfectly elastic. Its density is dependent on pressure, as well as on heat; and it does not follow, that air which may be heated, in consequence of its proximity to the earth, will give place to colder air from above. The pressure of the atmosphere varying with the elevation, one stratum of air may be as much rarer by the diminution of pressure, consequent to its altitude, as denser by the cold, consequent to its remoteness from the earth—and another may be as much denser by the increased pressure arising from its proximity to the earth, as rarer, by being warmer. Hence when unequally heated, different strata of the atmosphere do not always disturb each other. Yet after a time, the rarefaction in the lower stratum, by greater heat, may so far exceed that in an upper stratum, attendant on an inferior degree of pressure, that this stratum may preponderate, and begin to descend. Whenever such a movement commences, it must proceed with increasing velocity; for the pressure on the upper stratum, and of course its density and weight, increases as it falls; while the density and weight of the lower stratum, must lessen as it rises. Hence the change is, at times, so much accelerated, as to assume the characteristics of a tornado, squall, or hurricane. In like manner may we suppose, the predominant gales of our climate to originate. Dr. Franklin, long ago, noticed, that north-eastern gales are

felt in the south-westernmost portions of the continent first—the time of their commencement being found later, as the place of observation is more to the windward.

The Gulf of Mexico is an immense body of water—warm, in the first place, by its latitude—in the second place, by its being a receptacle of the current produced by the trade winds, which blow in such a direction, as to propel the warm water of the torrid zone into it, causing it to overflow and produce the celebrated Gulf Stream, by the ejection, to the north-east, of the excess received from the south-east. This stream runs away to the northward and eastward of the United States, producing an unnatural warmth in the ocean, as well as an impetus, which, according to Humboldt, is not expended, until the current reaches the shores of Africa, and even mixes with the parent flood under the equator. The heat of the Gulf Stream, enables mariners to ascertain, by the thermometer, when they have entered it: and in winter, this heat, by increasing the solvent power of the adjoining air, loads it with moisture—which, on a subsequent reduction of temperature, is precipitated in those well known fogs, with which the north-eastern portion of our continent, and the neighbouring seas and islands, especially Newfoundland and its banks, are so much infested. An accumulation of warm water in the Gulf of Mexico, adequate thus to influence the ocean at the distance of two thousand miles, may be expected, in its vicinity, to have effects proportionally powerful. The air immediately over the Gulf, must be heated, and surcharged with aqueous particles. Thus it will become comparatively light; first, because it is comparatively warm—and in the next place, because aqueous vapour, being much lighter than the atmospheric air, renders it more buoyant by its admixture.

Yet the density, arising from inferiority of situation in the stratum of air immediately over the Gulf, compared with that of the volumes of this fluid lying upon the mountainous country beyond it, may, to a certain extent, more than compensate for the influence of the heat and moisture derived

from the Gulf: but violent winds must arise, as soon as these causes predominate over atmospheric pressure, sufficiently to render the cold air of the mountains heavier.

When, instead of the air covering a small portion of the mountainous or table land in Spanish America, that of the whole north-eastern portion of the North American continent, is excited into motion, the effects cannot but be equally powerful, and much more permanent. The air of the adjoining country, first precipitates itself upon the surface of the Gulf, and afterwards, that, from regions more distant. Thus a current from the north-eastward, is produced below. In the interim, the air displaced by this current, rises, and being confined by the table land of Spanish America, and in part, possibly, by the trade winds, from passing off in any southernly course, it is, of necessity, forced to proceed over our part of the continent, forming a south-western current above us. At the same time, its capacity for heat being enlarged, by the rarefaction arising from its increased altitude, much of its moisture will be precipitated—and the lower stratum of the south-western current, mixing with the upper stratum of the cold north-eastern current below—there must be a prodigious condensation of aqueous vapour.

The reason is obvious, why this change is productive only of north-eastern gales—and that we have not northern gales, accompanied by the same phenomena. The course of our mountains, is from the north-east to the south-west. Thus no channel is afforded for the air proceeding to the Gulf, in any other course, than that north-eastern route which it actually pursues.

That the table lands of Mexico, are competent to prevent the escape, over them, of the moist warm air, displaced from the surface of the Gulf, must be evident, from the peculiar dryness of their climate—and the testimony of Humboldt.—According to this celebrated traveller, the clouds formed over the Gulf, never rise to a greater height than four thousand nine hundred feet—while the table land, for many hundred leagues, lies between the elevation of seven and nine

thousand feet. Consistently with the chemical laws, which have been experimentally ascertained to operate throughout nature, air, which has been in contact with water, can neither be cooled nor rarefied, without being rendered cloudy by the precipitation of aqueous particles. It follows, that the air displaced suddenly from the surface of the Gulf of Mexico, by the influx of cold air from the north-east, never rises higher than the elevation mentioned by Humboldt, as infested by clouds. Of course, it never crosses the table land, which, at the lowest, is 2000 feet higher.

Our north-western winds are produced, no doubt, by the accumulation of warm moist air upon the surface of the ocean, as those from the north-east are, by its accumulation on the Gulf of Mexico. But in the case of the Atlantic, there are no mountains to roll back, upon our hemisphere, the air displaced by the gales which proceed from it, and to impede the impulse, thus received, from reaching the Eastern Continent. Our own mountains may procrastinate the flood, and consequently render it more lasting and violent, when it can no longer be restrained. The direction of the wind, is naturally at right angles to the boundary of the aquatic region producing it, and to the mountainous barrier which delays the crisis.

The course of the North American coast is, like that of its mountains, from north-east to south-west—and the gales, in question, are always nearly north-west, or at right angles, to the mountains, and the coast. The dryness of our north-west wind, may be ascribed not only to its coming from the frozen zone, where cold deprives the air of moisture, but likewise to the circumstance above suggested, that the air of the ocean is not, like that of the Gulf, forced back over our heads, to deluge us with rain.

Other important applications may be made of our chemical knowledge. Thus, in the immense capacity of water for heat, especially when vaporized, we see a great magazine of nature, provided for mitigating the severity of the winter.—To cool this fluid, a much greater quantity of matter must

sustain a proportionable increase of its sensible heat.—Aqueous vapour is incessantly a vehicle for conveying the caloric of warmer climates, to colder ones. Mistaking the effect for the cause, snow is considered as producing cold, by the ignorant; but it has been proved, that as much heat is given out, during the condensation of aqueous vapour, as would raise twice its weight of glass to a red heat. Water, in condensing from the aëriform state, will raise ten times its weight one hundred degrees. The quantum of caloric, which can raise ten parts one hundred degrees, would raise one part one thousand degrees nearly, (or to a red heat visible in the day)—and this is independent of the caloric of fluidity, which would increase the result.

Further—the quantum of heat which would raise water to 1000, would elevate an equal bulk of glass to 2000. Hence we may infer, that from every snow, there is received twice as much caloric, as would be yielded by an equal depth of red hot powdered glass.

It is thus that the turbulent wave, which at one moment rocks the mariner's sea-boat, on the border of the torrid zone—transformed into a cloud, and borne away towards the arctic, soon after supports the sledge, or the snow-shoe, of an Esquimaux or Greenlander; successively cooling or warming the surrounding media, by absorbing or giving out the material cause of heat.

ESSAY,

ON THE QUESTION,

WHETHER THERE BE TWO ELECTRICAL FLUIDS, ACCORDING TO DU FAYE—OR ONE, ACCORDING TO FRANKLIN.

By those who allege the existence of two electrical fluids, much stress has been laid on the fact, that light bodies, when negatively electrified, separate from each other no less, than when in the opposite state. The absence and presence of a fluid, cannot, it is said, have the same effect of producing repulsion. To this, it has been answered, that the separation of such light bodies, is not the effect of repulsion, but of an attraction between them and the surrounding medium; which must equally ensue, whether they be electrified minus or plus: since, in either case, that diversity of electrical excitement, between them and the surrounding medium, arises, which is always productive of attraction.

In support of this view of the question, I propose to make a few observations.

In an electroscope with moveable coatings, like the galvanometer of Mr. Pepys,* the divergence of the leaves is faci-

* On the glass of the gold-leaf electrometer, small oblong strips of tin foil are usually pasted, on each side of the gold leaves. As these partial coatings extend to the metallic foot of the instrument, they are always neutral, when the foot is not intentionally insulated. Hence, whether the leaves are excited positively, or negatively, they are attracted, or made to diverge from each other, by means of the coatings. Instead of tin foil, pasted to the glass, Mr. Pepys employed strips of sheet brass, supported by screws. In proportion as these pieces of brass, thus substituted for the usual coatings, were, by means of the screws, approximated to the axis of the instrument, where the gold leaves were hanging, less excitement was found necessary to render them divergent.

litated, in proportion as the coatings are approximated to them. In this case, it must be admitted, that there is an attraction between the coatings and the leaves; for, were repulsion between the leaves the cause of their divergence, the approach of the coatings would not increase it.

It may, however, be supposed, that the repulsion between the similarly excited leaves, being counterbalanced, more or less, in all cases, by the electric tension of the surrounding medium, the coatings may permit the electric fluid to recede through them with greater facility—and thus lessen the electric tension, in the direction in which they are situated.

Were this supposition to avail, in the case of an electrometer with two leaves, it cannot apply in the case of an instrument lately contrived by me, in which, uninfluenced by the idea, that repulsion is the cause of electrometrical indications, I suspend only a single leaf. A brass ball, one-fourth of an inch in diameter, is so situated, that it may be made to touch the leaf, or retire from it to the distance of an inch, by means of a screw which supports it. (See plate I. fig. 1.) This instrument is evidently more simple, than any instrument with two leaves, and is at least as sensitive.*

It will be admitted, I presume, that the contact between the ball and the leaf, must result from attraction, whether the leaf be minus, or plus; and that this would not cease to be true, although a second leaf were, as usual, suspended beside the first.

In a common electrometer, it is usual to have pieces of tin foil pasted on the glass case opposite the gold leaves. If attraction be exercised between the leaves and coatings, when moveable, it must also be exercised by the fixed coatings, thus pasted on the glass. It is therefore established, that, when coatings, whether moveable or fixed, are employed, the divergence is not caused by repulsion. It cannot, then, be

* By means of an instrument with a single leaf, since constructed, I am enabled to detect the electricity produced, by one contact, between a copper and a zinc disk, each six inches in diameter.

reasonable to ascribe it to repulsion, though no coatings should be present, as when the leaves are suspended where nothing can attract them, unless the surrounding air; especially, as the air may be shown competent to perform the same office as the coatings, though not so well, on account of its presenting less matter within the same space. The lightness and mobility of the air, is no obstacle to this conclusion. When equally acted on in all directions, as it must be in the case in point, air resists like an arch, or an elastic solid. The electric attraction may have a tendency to condense it about the sphere of excitement, but cannot move one portion more than another. —This opinion of the agency of the air, is supported by the fact, that, in proportion as an exhausted receiver is larger, so will the difficulty of producing a divergency in the electrometrical leaves, situated within it, be increased. It would be difficult to procure a receiver so large, that gold leaves might not be made to diverge electrically in it, when exhausted;—but leaves of light paper, which will easily be made divergent, in pleno, or in vacuo, in a small vessel, will cease to be affected by a like influence, if suspended in an exhausted receiver sufficiently large. I am aware, that the air prevents the electric fluid from escaping, by its insulating power, and that when it is removed, electrometrical leaves cannot be sustained in a state of excitement, much higher than the rare medium about them. Thus situated, it may be alleged, that repulsion can no more act between them, to produce separation, than it does without them, to keep them together. But this reasoning would apply, equally, whether they be in a large, or in a small receiver; and, of course, does not account for the influence which the size of the receiver has on the divergency.

I will now adduce some additional facts and arguments, in opposition to the doctrine of two fluids.

According to Franklin, positive and negative, as applied to electricity, merely designate relative states of the same fluid. If, of three bodies, the first have more electricity than the second, and less than the third, it will be positive with re-

spect to the second, and negative with respect to the third. According to Du Faye, there is a radical difference between vitreous and resinous electricity—and though separately exercising intense action, they neutralize each other by union. It is universally admitted, that the fluid evolved by the prime conductor of a glass cylinder machine, and that evolved by the cushion, are of different kinds or states. According to the American theory, the first is positive, the last negative. According to the French theory, the first is vitreous, the last resinous.

Let there be two machines, No. 1, and No. 2, so arranged,* that the positive or vitreous conductor of one, may communicate with the negative or resinous conductor of the other.—In this case, the conductors, thus associated, form effectively, but one conducting mass; and one body, with a cushion on one side, and collecting points on the other, might be substituted for both. When this compound apparatus is put into action, it will be found that the intermediate conductor, tested by the resinous conductor of No. 1, is vitreous—but that it is resinous, when tested by the prime or vitreous conductor of No. 2. This result agrees with Franklin's doctrine, as above stated; but how can it be reconciled with the idea, that the electricities are radically different—that the same state of excitement may be confounded with either? It may, indeed, be alleged, that the fluid is never completely vitreous, or resinous, or neutral; that although the proportion of either fluid be great, it may still be increased; that one conductor may be more vitreous than a second, but less so than a third—or more resinous than a second, but less so than a third; and hence, in either case, may give sparks with either. This is, to me, nevertheless, a complicated and unsatisfactory solution of the difficulty.

Pursuant to the Franklinian theory, there can be no really neutral point; though the earth, as a reservoir, infinitely great, compared with any producible by art, furnishes an invariable

* See plate I. fig. 2.

standard of intensity, above and below which, all bodies electrically excited, are said to be minus, or plus.* It is perfectly consistent with this theory, that sparks should pass, as they are often seen to do, from conductors in either state—not only from one to the other, but to bodies nominally neutralized by their communication with the earth. As the difference between the electrical states of the oppositely electrified bodies, must be greater than between either of their states, and that of the great reservoir—the sparks between them will be longer, but, in all other characteristics, will be the same.—This practical result, is irreconcilable with the doctrine of two fluids—according to which, there can be no electricity in the earth, which is not in the state of a neutral compound, formed by these opposite electricities. For it would be an anomaly, to suppose, the reaction between a neutral compound, (a tertium quid) and either of its ingredients, to resemble, in intensity, and in its characteristic phenomena, the reaction which arises between the ingredients themselves.—As well might we expect aqueous vapour to explode with hydrogen or oxygen gas, as they do with each other.—Nothing can be more at war with the doctrine of definite proportions, of multiple volumes, and every analogy established by the chemistry of ponderable matter, than that two substances should combine, in every possible proportion, and with precisely the same phenomena; that they should be capable of neutralizing each other, and yet eagerly act as if never neutralized.

An argument in favour of the existence of two fluids, has been founded on the appearance of two burs, when a card is

* In some discussions which took place some years ago, between Mr. Donovan and Mr. De Luc, in Nicholson's Journal, it was erroneously charged against Franklin's doctrine, that he supposed that there was an absolute state of neutrality. The doctrine of one universal fluid, is, to me, obviously irreconcilable with that idea, otherwise than as above explained.—The quantity of electricity in the globe, is as unalterable in any sensible degree, as the quantity of water in the ocean; and it may therefore be assumed to be invariably the same.

pierced by an electric discharge. This phenomenon is as difficult of explanation, agreeably to Du Faye's theory, as Franklin's. If a current of electricity, flowing in one direction, should produce a bur, in piercing a card on the side towards which it flows, two currents should be productive of none—one current being precisely adequate to neutralize the other, according to the premises. The appearance may be explained by either doctrine, as resulting from intense attraction between the paper and the knobs transmitting the discharge.

It has been observed, in favour of the French theory, that, when the hands are made the medium of a feeble discharge, a shock is felt, simultaneously, in the fingers only of each hand; that, as the shock is made stronger, it affects the wrist, the arm, and finally the chest. This is considered as proving the operation of two distinct fluids; for, were the shock the effect of one current, it would be experienced equally, though feebly, throughout the whole of the circuit. Admitting that such a current were necessary to the discharge, agreeably to Franklin's theory, it ought to be felt most in the fingers, where it is most concentrated—as torrents flow with greater violence, in proportion as their channels are narrowed. A current passing from one coating of a Leyden jar to another, is far from being necessary to restore the equilibrium of its surfaces. As soon as a circuit is established between them by the hands, the electricity in the hand which touches the negative surface, flows into it to supply the deficiency; while the hand which touches the positive surface, receives from it a surcharge. It is a case analogous to that of a syphon, in which a fluid, forcibly displaced from its level, is suddenly relieved from restraint. Both columns would move at the same time, and with a velocity greater in any part, in proportion as the diameter of the syphon should be less. The deficit caused in the hand in contact with the negative coating, is supplied by electricity from the arm; and this, again, from the body, where, if the charge be inconsiderable, it is so much diffused as not to be perceived. In like manner, a *slight* sur-

charge received by the hand in contact with the positive coating, is diffused, as it proceeds up the arm to the chest, so as to be too feeble to be felt there.

A piece of tin foil, interposed between paper, has been found not to be perforated by a charge, which had pierced the paper on both sides of it.

If there were but one current, it is alleged that tin foil, situated as above mentioned, would be pierced during its passage from one coating to the other—*a fortiori*, then, it should be pierced, if two currents be necessary, passing each other. Besides, the explanation afforded, in the case of a shock received by the hands, applies to this: owing to its great conducting power, the tin foil diffuses the attraction from each side, so much, as not to be damaged by it.

DESCRIPTION

OF AN

ELECTRICAL PLATE MACHINE,

The Plate mounted horizontally, and so as to show both negative and positive Electricity.

Illustrated by Engravings.

The power of Electrical Plate Machines, has been generally admitted to be greater, than that of machines with cylinders. —The objection to the former has been, the difficulty of insulating the cushions, so as to display the negative electricity. —Excepting the Plate Machine contrived by Van Marum, I have read of none in which this difficulty has been surmounted. It is still insisted upon, by respectable electricians, as if it had not been sufficiently removed by his contrivance.

I presume, therefore, that a description of a Plate Machine, by which both electricities may be shown, and which, after two years' experience, I prefer on every account, may not be unacceptable to the public.*

My Plate (thirty-four inches in diameter) is supported upon an upright iron bar, about an inch in diameter, covered by a very stout glass cylinder, four inches and a half in diameter, and sixteen inches in height, open only at the base, through which the bar is introduced, so as to form its axis. The summit of the bar is furnished with a block of wood, turned to

* See plate I. fig. 3.

fit the cavity, formed at the apex of the cylinder, and cemented therein. The external apex of the cylinder is cemented into a brass cap, which carries the plate. The glass cylinder is liable to no strain; it is only pressed where it is interposed between the block of wood within, and the brass cap without. The remaining portion of the cylinder bears only its own weight, while it effectually insulates the plate from the iron axis. The brass cap is surmounted by a screw and flange—by means of which, a corresponding nut, and disks of cork, the plate is fastened. A square table serves as a basis for the whole. The iron axis, passing through the cover of the table, is furnished with a wooden wheel of about twenty inches diameter, and terminates below this wheel in a brass step, supported on a cross of wood, which ties the legs of the table diagonally together. The wheel is grooved, and made to revolve by a band, which proceeds from around a vertical wheel, outside of the table. This external wheel has two handles; it may of course be turned by means either of one or both. It is supported on two strips of wood, which, by means of screws, may be protruded, lengthwise, from cases, which confine them from moving in any other direction. By these means, the distance between the wheels may be varied at pleasure, and the tension of the band duly adjusted.

Nearly the same mode of insulation and support, which is used for the plate, is used in the case of the conductors.— These consist, severally, of arched tubes of brass, of about an inch and a quarter in diameter, which pass over the plate from one side of it to the other, so as to be at right angles to, and at a due distance from, each other. They are terminated by brass balls and caps, which last are cemented on glass cylinders, of the same dimensions, nearly, as that which supports the plate. The glass cylinders are suspended upon wooden axes, surmounted by plugs of cork, turned accurately to fit the space which they occupy. The cylinders are kept steady,

below, by bosses of wood, which surround them. In this way, the conductors are effectually insulated, while the principal strain is borne by the wooden axes.

I consider this mode of mounting an Electrical Plate, preferable to any with which I am acquainted. The friction, arising from the band, may render the working of the machine a little harder for one person, with one hand; but then it affords the advantage, that two persons may be employed for this purpose, or one may use both hands at once. The intervention of the band, secures the plate from being cracked, by a hasty effort to put it into motion, when adhering to the cushions, as it does at times; and the screws, by means of which the distance of the wheels is increased, obviate the liability of the band to slacken with wear.

ACCOUNT

OF AN

ELECTROMETER WITH A SINGLE LEAF,*

By which the Electricity, excited by the touch of heterogeneous metals, is rendered obvious, after a single contact.†

A SINGLE leaf, suspended from a disk of zinc six inches in diameter, constitutes the top of the instrument. Opposite to this single leaf, is a ball, supported on a wire, which may be made to approach the leaf, or recede from it, by means of a screw. A disk of copper, with a glass handle, accompanies the instrument.‡

The electricity produced by the contact of copper and zinc, is rendered sensible in the following manner. Place the disk of copper, on the disk of zinc, (which forms the canopy of the Electrometer)—take the micrometer screw in one hand, touch the copper disk with the other, and then lift this disk from the zinc. As soon as the separation is effected, the

* Since the account of the Electrometer above described, was published, I have found, that an "Electro-micrometer" was employed, by a Mr. Veau Delaunay, in France, in which, either one, or two leaves were suspended, and their sensibility increased, or diminished, by the approximation, or recession, of pieces of metal, by screws. I believe, however, that my contrivance is original, so far as respects the production of electrical movements, by a single contact of heterogeneous metallic surfaces, and making one of the exciting disks serve as a cap of the instrument.

† This instrument is represented in one of the plates at the end of the book, fig. 7.

‡ For the experiment with this Electrometer, a metallic handle would answer. Its being of glass, enabled me to compare the indication, thus obtained, with that obtained by a Condenser.

gold leaf will strike the ball, usually, if the one be not more than a twentieth of an inch, apart from the other.* Ten contacts of the same disks, of copper and zinc, will be found necessary to produce a sensible divergency in the leaves of the Condensing Electrometer. That the phenomenon arises from the dissimilarity of the metals, is easily shown, by repeating the experiment with a zinc disk, in lieu of a disk of copper. The separation of the homogeneous disks, will not be found to produce any contact, between the leaf and ball.

I believe no mode has been heretofore contrived, by which the electrical excitement, resulting from the contact of heterogeneous metals, may be detected by an Electroscope, without the aid of a condenser.

It is probable, that the sensibility of this instrument, is dependent on that property of electricity, which causes any surcharge of it, which may be created in a conducting surface, to seek an exit at the most projecting termination, or point, connected with the surface. This disposition is no doubt rendered greater, by the proximity of the ball, which increases the capacity of the gold leaf to receive the surcharge, in the same manner, as the uninsulated disk of a condenser, influences the electrical capacity of the insulated disk, in its neighbourhood.

It must not be expected, that the phenomenon above described, can be produced in weather unfavourable to electricity. Under favourable circumstances, I have produced it, by means of a smaller Electrometer, of which the disks are only two and a half inches in diameter.†

The construction, as respects the leaf, and the ball, regulated by the micrometer screw, remaining the same—the cap of a Condensing Electrometer, and its disks, may be substituted for the zinc disk.

* I have observed it to strike at nearly double this distance.

† I think I have seen an effect from a disk only an inch in diameter, or from a zinc disk, having a copper socket to its handle.

A MEMOIR

ON

SOME NEW MODIFICATIONS OF GALVANIC APPARATUS,

WITH

Observations in support of his Theory of Galvanism.

BY ROBERT HARE, M. D.

Professor of Chemistry in the University of Pennsylvania.*

I HAD observed that the ignition, produced by one or two Galvanic pairs, attained its highest intensity, almost as soon as they were covered by the acid employed to excite them, and ceased soon afterwards—although the action of the acid should have increased during the interim. I had also remarked, in using an apparatus of three hundred pairs of small plates, that a platina wire, (number sixteen) placed in the circuit, was fused, in consequence of a construction, which enabled me to plunge them all nearly at the same time. Hence it was conceived, that, in the most improved modes, previously pursued, of operating with extensive Voltaic series, the maximum of deflagrating power, could not have been attained. The plates had been generally arranged in distinct troughs, rarely containing more than twenty pairs. Those of the great apparatus of the Royal Institution, employed by

* First published in the Philadelphia Medical Journal.

Sir Humphry Davy, had only ten pairs in each. Two thousand such pairs were to be placed in the acid, in two hundred such troughs; and the whole of these to be connected, ere the poles could act. Consequently, the effect which arises, immediately after immersion, would be lost in the troughs, first arranged, before it could be produced in the last; and no effort appears to have been made, to take advantage of this transient accumulation of power, either in using that magnificent combination, or any other of which I have read.

In order to observe the consequence of simultaneous immersion, with a series sufficiently numerous to test the correctness of my expectations, eighty concentric coils of copper and zinc, duly connected by arches of metal, were so suspended by a beam and levers, as that they might be made to descend into, or rise out of, the acid in an instant. The zinc sheets were about nine inches by six, the copper fourteen by six—more of this metal being necessary, as in every coil it was made to commence within the zinc, and completely to surround it without. The sheets were coiled, so as not to leave between them an interstice wider than a quarter of an inch. Each coil is in diameter about two inches and a half, so that all may descend freely into eighty glass jars, two inches and three quarters diameter inside, and eight inches high, duly stationed to receive them.*

My apparatus, being thus arranged, two small lead pipes were severally soldered to each pole, and a piece of charcoal, about a quarter of an inch thick, and an inch and a half long, tapering a little at each extremity, had these severally inserted into the hollow ends of the pipes. The jars being furnished with diluted acid, and the coils suddenly lowered into them, no vestige of the charcoal could be seen: it was ignited so intensely, that those portions of the pipes, by which it had been embraced, were destroyed.

In order to avoid a useless and tiresome repetition, I will here state, that the coils were only kept in the acid while the

* See 1st Plate of the Galvanic Deflagrator.

action at the poles was at a maximum, in the experiment just mentioned, and in others which I am about to describe, unless where the decomposition, produced by water, is spoken of, or the sensation excited in the hands. I designate the apparatus with which I performed them, as the Galvanic Deflagrator, on account of its superior power, in proportion to its size, in causing deflagration; and as, in the form last adopted, it differs from the Voltaic pile, in the omission of one of the elements, heretofore deemed necessary to its construction.

Desirous of seeing the effect, of the simultaneous immersion of my series, upon water—the pipes soldered to the poles, were introduced into a vessel containing that fluid. No extraordinary effect was perceived, until they were very near, when happening to touch each other, almost at the same time a vivid flash was observed, and they were found fused and incorporated, at the place of contact. I next soldered, to each pipe, a hollow brass cylinder, the bore being five-tenths of an inch in diameter. These cylinders were made to receive the tapering extremities of a piece of charcoal, about two inches long, so as to complete the circuit. The submersion of the coils, caused the most vivid ignition in the coal.—It was instantaneously, and entirely, on fire. A piece of platina, of about a quarter of an inch diameter, in connexion with one pole, was instantly fused, at the end, on being brought in contact with some mercury, communicating with the other pole. When two cylinders of charcoal, having hemispherical terminations, were fitted into the brass cylinders, duly connected with the apparatus, and brought nearly into contact, a most vivid ignition took place, and continued after they were removed, about a half or three quarters of an inch apart—the interval rivalling the sun in brilliancy. The most intense action seems to arise, from placing a platina wire, of about the eighth of an inch diameter, in connexion with one pole, and bringing it in contact with, and afterwards removing it a small distance apart from, a piece of charcoal (fresh from the fire) affixed to the other pole.

As points are pre-eminently capable of carrying off, without being injured, a current of the electrical fluid, and very ill qualified to conduct caloric—while, by facilitating radiation, charcoal favours the separation of caloric from the electricity which does not radiate. This result seems consistent with my theory, that caloric and electricity are evolved by the pile, as collateral products—but is inconsistent with the doctrine, according to which the caloric is an effect of electricity.* The finest needle is competent to discharge the product of the most powerful machine without detriment, if received gradually as generated by them. Platina points, as small as those which were melted like wax in my experiments, are used as tips to lightning rods without injury, unless in sudden discharges produced under peculiar circumstances.†

* According to the theory here alluded to, the Galvanic fluid owes its properties to caloric and electricity—the former predominating in proportion to the size of the pairs—the latter in proportion to the number; being in both cases excited by a powerful acid. Hence in batteries, which combine both qualifications sufficiently, as in all those intervening between Children's large pairs of two feet eight inches by six feet, and the 2000 four-inch pairs of the Royal Institution, the phenomena indicate the presence of both fluids. In De Luc's column, where the size of the pairs is insignificant, and the energy of interposed agents feeble, we see electricity evolved, without any appreciable quantity of caloric. In the calorimotor, where we have size only, the number being the lowest possible, we are scarcely able to detect the presence of electricity.

When the fluid contains enough electricity, to give a projectile power adequate to pass through a small space in the air, or through charcoal, which impedes or arrests the caloric, and favours its propensity to radiate, this principle is evolved. Hence the intense heat, observed under those circumstances which rarefies the air, so that the length of the jet, from one pole to the other, may be extended after its commencement: hence the portions of the circuit nearest to the intervening charcoal, or heated space, are alone injured; and even non-conducting bodies, as quartz, introduced into it, are fused—and hence a very large wire may be melted by the fluid, received through a small wire imperceptibly affected.

See Silliman's Journal, No. 6, Vol. 1.—Thomson's Annals, Sept. 1810.—Tilloch's Philosophical Magazine, Oct. 1819.

† See Lecture on Electricity, page 23 of this Supplement.

The following experiment, I conceive to be very unfavourable to the idea, that Galvanic ignition arises from a current of electricity, unaccompanied by a current of caloric.

A cylinder of lead, of about a quarter of an inch diameter, and about two inches long, was reduced to the thickness of a common brass pin, for about three quarters of an inch.—When one end was connected with one pole of the apparatus, the other remained suspended by this filament—yet it was instantaneously fused, by contact with the other pole. As all the calorific fluid which acted upon the suspended knob, must have passed through the filament by which it hung, the fusion could not have resulted from a pure electrical current, which would have dispersed the filament, ere a mass, fifty times larger, had been perceptibly affected. But if we suppose a union between caloric and electricity, which renders them inert till circumstances favour a disunion, as on the passage of the compound fluid through charcoal, the air, or a vacuum, the phenomena are not so inexplicable.

In operating with the deflagrator, I have found a brass knob, of about five-tenths of an inch in diameter, to burn on the superficies only—where alone, as I suppose, caloric is separated, so as to act on the mass.

Having found, that four Galvanic surfaces acted well in one recipient,* I was tempted, by means of the eighty coils, to extend that construction. It occurred to me, that attempts of this kind had failed, from using only one copper for each zinc plate. The zinc had always been permitted to react towards the negative, as well as the positive pole. My coils being surrounded by copper, it seemed probable, that, if electro-caloric were, as I had suggested, carried forward by circulation, arising from Galvanic polarity, this might act within the interior of the coils, yet not be exerted between one coil and another. I had, accordingly, a trough constructed with a partition along the middle, so as to receive

* See Plate of the Calorimotor, at the end of the book.

forty coils on one side, and a like number on the other.—This apparatus, when in operation, excited a sensation, scarcely tolerable, in the backs of the hands—and a most intense ignition took place, on bringing a metallic point, connected with one pole of the series, into contact with a piece of charcoal fastened to the other. A cylinder of platina, nearly a quarter of an inch in diameter, and tapering a little at the end, was fused, and burned, so as to sparkle and fall in drops. A ball of brass, of about half an inch diameter, was seen to burn on its surface with a green flame. Tin foil, or tinsel, rolled up into large coils of about three quarters of an inch thick, were rapidly destroyed, as was a wire of platina of No. 16. When platina wires in connexion with the poles, were brought into contact with sulphuric acid, there was an appearance of lively ignition.

Apprehending that the partition in the trough did not sufficiently insulate the poles from each other, as they were but a few inches apart, moisture or moistened wood intervening, I had two troughs made, each to hold forty pairs, and took care that there should be a dry space, about four inches broad, between them. They were first filled with pure river water, there being no saline nor acid matter to influence the plates, unless the very minute quantity which might have remained on them from former immersions. Yet the sensation produced by them, on the backs of my hands, was painful—and a lively scintillation took place, when the poles were approximated. Dutch gold leaf was not sensibly burned, though water was found decomposable by wires properly affixed.—No effect was produced on potash, the heat being inadequate to fuse it.

A mixture of nitre and sulphuric acid, being added to the water in the troughs, charcoal from the fire was afterwards vividly ignited—and when, attached to one pole, a steel wire was interposed between it and the other pole, the most vivid ignition which I ever saw, was induced. I should deem it imprudent to repeat the experiment without glasses, as my eyes, though unusually strong, were affected for forty-eight

hours afterwards. If the intensity of the light did not produce an optical deception, by its distressing influence upon the organs of vision, the charcoal assumed a pasty consistence, as if in a state approaching to fusion. That charcoal should be thus softened, without being destroyed by the oxygen of the atmosphere, may be ascribed to the excessive rarefaction, or, as I suspect, to the protection afforded, by an atmosphere of volatilized carbon. This last mentioned impression arose from observing, that when the experiment was performed in vacuo, there was a lively scintillation, as if the carbon, in an aëriform state, acted as a supporter of combustion on the metal.

A wire of platina (No. 16) was fused into a globule on being connected with the positive pole, and brought into contact with a piece of pure hydrate of potash, situated on a silver tray in connexion with the other pole. The potash became red hot, and was deflagrated rapidly, with a flame having the rosy hue of potassuretted hydrogen.

A steel wire of about one-tenth of an inch in diameter, affixed to the negative pole, was passed up through the axis of an open necked inverted bell glass, filled with water. A platina wire, No. 16, attached to a positive pole, being passed down to the steel wire, both were fused together, and cooling, could not be separated by manual force. Immediately after this incorporation of their extremities, the platina wire became incandescent for a space of some inches above the surface of the water.

A piece of silvered paper about two inches square, was folded up, the metallic surface outward, and fastened into vices affixed to the poles. Into each vice a wire was screwed at the same time. The fluid generated by the apparatus, was not perceptibly conveyed by the silvered paper, as it did not prevent the wires severally attached to the poles, from decomposing water, or producing ignition by contact.

In my Memoir on my theory of Galvanism, I suggested, that the decomposition of water, which Wollaston effected

by mechanical electricity, might not be the effect of divellent attraction, like those excited by the poles of a Voltaic pile, but of a mechanical concussion, as when wires are dispersed by the discharge of an electrical battery. In support of that opinion, I will now observe, that he could not prevent hydrogen and oxygen from being extricated at each wire, instead of hydrogen being given off only at one, and oxygen at the other, as is invariably the case when the Voltaic pile is employed. That learned and ingenious philosopher, in concluding his account of this celebrated experiment, says:—"But in fact the resemblance is not complete, for in every way in which I have tried it, I observed each wire gave out both oxygen and hydrogen gas, instead of their being formed separately as by the electric pile."

Is it not reasonable to suppose, that an electrical shock may dissipate any body into its elementary atoms, whether simple or compound, so that no two particles would be left together, which can be separated by physical means?

Looking over Singer's Electricity, a recent and most able modern publication, I find, that in the explosion of brass wire by an electrical battery, the copper and zinc actually separated.

He says, page 186, "Brass wire is sometimes *decomposed* by the charge; the copper and zinc, of which it is formed, being separated from each other, and appearing in their distinct metallic colours." On the next page in the same work, I find, that the oxides of mercury, and tin, are reduced by electrical discharges. "Introduce," says the author, "some oxide of tin, into a glass tube, so that when the tube is laid horizontal, the oxide may cover about half an inch of its lower internal surface. Place the tube on the table of the universal discharger, and introduce the pointed wires into its opposite ends, that the portion of oxide may lay between them. Pass several strong charges in succession through the tube, replacing the oxide in its situation, should it be *dispersed.* If the charges are sufficiently powerful, a part of the tube will

soon be stained with metallic tin, which has been revived by the action of transmitted electricity."

It cannot be alleged, that, in the decompositions described in this quotation, those divellent polar attractions are exercised, which characterise wires proceeding from the poles of a Voltaic apparatus. The particles were *dispersed from*, instead of being *attracted to*, the wires, by which the influence was conveyed among them. This being undeniable, it can hardly be advanced that, while we have one mode of explaining the separation of the elements of brass, by an electrical discharge—another is to be resorted to, in explaining the separation of the elements of water, by the same agent: that one rationale is to be adopted, in order to account for the liberation of oxygen from tin—and another, when it is liberated by like means from hydrogen.

In the experiment, in which copper was precipitated, by the same philosopher, at the negative pole, we are not informed whether the oxygen and acid, in union with it, were attracted to the other—and the changes produced in litmus, are mentioned as successive, not as simultaneous. The violet and red rays of the spectrum, have an opposite chemical influence, in some respects analogous to that of the Voltaic poles—but it does not follow, that Galvanism and light, are produced by the same cause. Besides admitting, that the feeble results, obtained by Wollaston and Van Marum, with mechanical electricity, are perfectly analogous to those ordinarily obtained by the Galvanic fluid,—before they can furnish an objection to my hypothesis, it ought to be shown, that the union between caloric and electricity, which I suppose productive of Galvanic phenomena, cannot be produced by that very process. If they combine to form the Galvanic fluid, when extricated by ordinary Galvanic action, they must have an affinity for each other. When electricity enters the pores of a metal, it may unite with its caloric. In Wollaston's experiments, being constrained to enter the metal, it may combine with enough of its caloric to produce, when emitted,

results slightly approaching to those of a fluid, in which caloric exists in greater proportion.

But, once more I demand, why, if mechanical electricity be too intense to produce Galvanic phenomena, should it be rendered more capable of producing them, by being still more concentrated?

If the one be generated more copiously, the other more intensely,—the first will move slowly in a large stream, the last rapidly in a small stream. Yet, by narrowing the channel of the more rapid current, Wollaston is supposed to render it more like the other—that is, produces a resemblance, by magnifying the feature in which the dissimilitude exists.

It has been imagined, that the beneficial effect of his contrivance, arises from the production of a continued stream, instead of a succession of sparks; but if a continued stream were the only desideratum, a point, placed near the conductor of a powerful machine, would afford this requisite—as the whole product may, in such cases, be conveyed by a sewing needle, in a stream perfectly continuous.

As yet, no adequate reasons have been given why, in operating with the pile, it is not necessary, as in the processes of Van Marum and Wollaston, to enclose the wires in glass or sealing wax, in order to make the electricity emanate from a point within a conducting fluid. The absence of this necessity, is accounted for, according to my hypothesis, by the indisposition which the electric fluid has to quit the caloric in union with it, and the almost absolute incapacity which caloric has to pass through fluids, unless by circulation. I conceive, that, in Galvanic combinations, electro-caloric may circulate through the fluid, from the positive to the negative surface—and through the metal, from the negative to the positive. In the one case, caloric subdues the disposition which electricity has to diffuse itself through fluids, and carries it into circulation. In the other, as metals are excellent conductors of caloric, the prodigious power which electricity has to pervade them, agreeably to any attractions which it

may exercise, operates almost without restraint. This is fully exemplified in the Galvanic Deflagrator, where eighty pairs are suspended, withsut insulation, in two recipients, forty successively in each, and yet decompose potash with the utmost rapidity, and produce an almost intolerable sensation,* when excited only by fresh river water.

I have already observed, that the reason why Galvanic apparatus, composed of pairs consisting each of one copper and one zinc plate, has not acted well without insulation,† was, because in such apparatus, electro-caloric could retrocede in the negative, as well as advance in the positive direction.

Pursuant to the doctrine, which supposes the same quantity of electricity, varying in intensity in the ratio of the number of pairs to the quantity of surface, to be the sole agent in Galvanic ignition—the electrical fluid, as evolved by Sir H. Davy's great pile, must have been nearly two thousand times more intense, than as evolved by a single pair; yet it gave sparks, at no greater distance than the thirtieth or fortieth of an inch. The intensity of the fluid, must be at least as much greater in one instance, than in another, as the sparks produced by it are longer. A fine electrical plate machine, of thirty-two inches diameter, will give sparks at ten inches.—Of course the intensity of the fluid which it emits, must be three hundred times greater, than that emitted by two thousand pairs. The intensity produced by a single pair, must be two thousand times less, than that produced by the great pile—and of course six hundred thousand times less, than that produced by a good electrical plate of thirty-two inches. Yet a single pair, of about a square foot in area, will certainly deflagrate more wire, than a like extent of coated surface, charged by such a plate.

* I do not say shock, as it is more like the permanent impression of hot pointed wire, especially when an acid is used.

† That is, with the same mass of conducting fluid, in contact with all the surfaces, instead of being divided into different portions, each restricted in its action to one copper and one zinc plate.

According to Singer, it requires about one hundred and sixty square inches of coated glass, to destroy watch pendulum wire :—a larger wire may be burned off, by a Galvanic battery of a foot square. But, agreeably to the hypothesis in dispute, it compensates, by quantity, for the want of intensity. Hence the quantity of fluid in the pair, is six hundred thousand times greater, while its intensity is six hundred thousand times less—and *vice versa* of the coated surface. Is not this absurd? What does intensity mean, as applied to a fluid? Is it not expressed, by the ratio of quantity to space? If there be twice as much electricity within one cubic inch, as within another, is there not twice the intensity? But, the one acts suddenly, it may be said—the other slowly. But whence this difference? They may both have exactly the same surface to exist in. The same zinc and copper plates may be used for coatings first, and for a Galvanic pair afterwards. Let it be said, as it may in truth, that the charge is, in the one case, attached to the glass superficies—in the other, exists in the pores of the metal. But, why does it avoid these pores in one case, and reside in them in the other? What else resides in the pores of the metal, which may be forced out by percussion? Is it not caloric? Possibly, unless under constraint, or circumstances favourable to a union between this principle and electricity, the latter cannot enter the metallic pores, beyond a certain degree of saturation; and hence an electrical charge does not reside in the metallic coatings of a Leyden phial, though it fuses the wire which forms a circuit between them.

It is admitted, that the action of the Galvanic fluid is upon, or between, atoms—while mechanical electricity, when uncoerced, acts only upon masses. This difference has not been explained, unless by my hypothesis, in which caloric, of which the influence is only exerted between atoms, is supposed to be a principal agent in Galvanism. Nor has any other reason been given, that water, which dissipates pure electricity, should cause the Galvanic fluid to accumulate.—

From the prodigious effect which moist air, or a moist surface, has, in paralyzing the most efficient electrical machines, I am led to suppose, that the conducting power of moisture, so situated, is greater than that of water under its surface. The power of this fluid, to conduct mechanical electricity, is unfairly contrasted with that of a metal, when the former is enclosed in a glass tube.

According to Singer, the electrical accumulation is as great when water is used, as when more powerful menstrua are employed; but the power of ignition is wanting, until these are resorted to. De Luc showed, by his ingenious dissections of the pile, that electricity might be produced *without*, or *with*, chemical power. The rationale of these differences, never has been given, unless by my theory, which supposes caloric to be present in the one case, but not in the other.—The electric column was the fruit of De Luc's sagacious inquiries, and afforded a beautiful and incontrovertible support to the objections which he made to the idea, that the Galvanic fluid is pure electricity, when extricated by the Voltaic pile in its usual form. It showed, that a pile, really producing pure electricity, is devoid of the chemical power of Galvanism.

We are informed by Sir H. Davy, that, when charcoal points in connexion with the poles of the magnificent apparatus, with which he operated, were first brought nearly into contact, and then withdrawn four inches apart, there was a heated arch formed between them, in which such non-conducting substances as quartz, were fused. I believe it impossible to fuse electrics by mechanical electricity. If opposing its passage, they may be broken—and if conductors near them be ignited, they may be acted on by those ignited conductors, as if otherwise heated; but I will venture to predict, that the slightest glass fibre will not enter into fusion, by being placed in a current from the largest machine or electrical battery.

I am induced to believe, that we must consider light, as well as heat, an ingredient in the Galvanic fluid; and think it possible, that, being necessary to vitality in animals, as well as vegetables, the electric fluid may be the vehicle of its distribution.

Since writing the above, I have endeavoured, in every mode which I could devise, to ignite charcoal by electricity. Exposed to the discharge of a powerful battery, in pieces tapering to a point, in a glass tube, in thin strips, and in powder, by means of the glass usually employed for inflaming ether, it was either uninfluenced, or merely dispersed, without the smallest symptom of ignition, or even of increased warmth. Yet fulminating mercury was flashed by the discharge, under the same circumstances as those in which the powdered charcoal had been subjected to it.—Pointed wires were covered with spermaceti, and exposed to a current from a fine plate machine of thirty-two inches in diameter—yet no sign of fusion appeared. Nor was a differential thermometer filled with ether, according to Dr. Howard's plan, affected sensibly; though the warmth of a finger applied to the bulb, caused the fluid in the stem to move nearly a foot.

I mentioned, (page 33) that when a knob of lead, suspended by a filament to one of the poles of my deflagrator, was made to touch the other pole of the same instrument, the knob was fused, the filament uninjured. I find the reverse is the case, when a knob, suspended by a filament, is made the medium of discharging an electrical battery. The filament is destroyed, the knob remains unchanged. It must be evident, therefore, that Galvanic and electrical ignition, are extremely discordant in their characteristics.

It is also mentioned, (page 35) that a piece of silvered paper two inches square, proved inadequate to discharge my Galvanic apparatus of coils—yet, at a distance seventy times greater, a strip of the same paper, one-third of an inch wide, and twenty inches long, caused an instantaneous discharge of the electrical battery.

LETTER

From Robert Hare, M. D. *Professor of Chemistry in the University of Pennsylvania, to* B. Silliman, *Professor of Chemistry in Yale College, respecting some improved forms of the Galvanic Deflagrator—and on the superiority of its deflagrating power.**

After I had discovered that the deflagrating power, of a series of Galvanic pairs, was surprisingly increased, by their simultaneous exposure, after due repose, to the acid—various modes suggested themselves, of accomplishing this object.—In the apparatus which I sent you, the coils, being all suspended to two beams, could be lowered into troughs, containing the acid.† In another apparatus, of which I afterwards gave you an account, with an engraving for your Journal, the troughs containing the acid, were made to rise, so that all the plates might be immersed at once.‡

A better mode has since occurred to me. Two troughs are joined lengthwise, edge to edge, so that when the sides of the one are vertical, those of the other must be horizontal. Hence, by a partial revolution of the two troughs, thus united, upon pivots which support them at the ends, any fluid which may be in one trough, must flow into the other—and, reversing the motion, must flow back again. The Galvanic series being placed in one of the troughs, the acid in the

* Published first in Silliman's Journal.

† See 1st Plate of the Deflagrator. ‡ See 2d Plate of the Deflagrator.

other, by a movement such as above described, the plates may all be instantaneously subjected to the acid, or relieved from it. The pivots are made of iron, coated with brass or copper, as less liable to oxidizement. A metallic communication is made between the coating of the pivots, and the Galvanic series within. In order to produce a connexion between one recipient of this description, and another, it is only necessary to allow a pivot of each trough to revolve on pieces of sheet copper, severally soldered to the different ends of a rod of metal. To connect with the termination of the series, the leaden rods, (to which are soldered the vices, or spring forceps, for holding the substances to be exposed to the deflagrating power,) one end, of each of the lead rods, is soldered to a piece of sheet copper. The pieces of copper, thus soldered to the lead rods, are then to be duly placed under the pivots, which are of course to be connected with the terminations of the series. The last mentioned connexion is conveniently made by means of straps of copper, severally soldered to the pivots, and the poles of the series, and screwed together by a hand-vice.

Fig. 1, plate 3,* represents an apparatus, consisting of two troughs, each ten feet long, constructed in the manner which I have described. Each trough is designed to contain one hundred and fifty Galvanic pairs. The Galvanic series in the upper trough, is situated as when not subjected to the acid. In the representation of the lower trough, the Galvanic series is omitted, in order that the interior may be better understood. The series belonging to this trough, may be observed below it, in three boxes, each containing fifty pairs, fig. 2. In placing these boxes in the trough, some space is left, between them and that side of the trough on which the acid enters, so that instead of flowing over them, it may run down outside, and rise up within them.

The pairs of the series consist of copper cases, about seven inches long, by three inches wide, and half an inch thick—

* See 3d Plate of the Deflagrator.

each containing a plate of zinc. equidistant from its sides, and prevented from touching it by grooved strips of wood.—Each plate of zinc is soldered to the next case of copper, on one side. This may be understood from the diagram, fig. 3. It must be observed, that the copper cases are open only at the bottom and top. They are separated from each other by very thin veneers of wood.

Fig. 4, represents a smaller trough, differing from the others only in length. This I made, with a view to some experiments on the comparative power of the Galvanic pairs of the form of copper cases, with zinc plates, above described, and those made on Cruickshank's plan, or of the form used by Sir H. Davy, in the porcelain troughs.

Fig. 5, represents a box, containing one hundred Cruickshank plates, (each consisting of a plate of zinc, and a plate of copper, soldered face to face) slid into grooves, at a quarter of an inch distance from each other; all the copper surfaces being in one direction, and all the zinc surfaces in the other. In this case the zinc plates are exposed only on one side.—The sum of the surfaces on which the acid can act, is therefore the same as in a deflagrator of fifty pairs, in which each zinc plate is assailable on both sides. It ought to be understood, that the box containing the one hundred Cruickshank plates, is open at bottom, and is of such dimensions as to occupy the place of a box, containing fifty pairs of the deflagrator, receiving the acid in its interstices from below, in the same manner, by a partial revolution of the trough, fig. 4.

Fig. 6, represents a box, containing two hundred Cruickshank plates. This differs from the common Cruickshank trough, only, in having the interstices as narrow as those between the copper and zinc surfaces of the deflagrator pairs, represented by fig. 2; and in the mode in which the acid is thrown off, or on, the whole series, which does not differ, materially, from that described in the instance of fig. 1.

On contrasting the series of fifty, (fig. 4) with Cruickshank's plates in the box, (fig. 5) the deflagrating power of the latter was found comparatively feeble—and even when

compared with the Cruickshank trough, (fig. 6) in igniting metals, or carbon, the fifty pairs (fig. 4) were found greatly superior. The shock from the Cruickshank trough was more severe. You must recollect, that in former experiments, I found that Galvanic plates, with their edges exposed as they are in the porcelain troughs, used by Sir H. Davy, were almost inefficient, when used without insulation, as are the pairs of the deflagrator. This demonstrates, that an unaccountable difference is producible, in Galvanic apparatus, by changes of form or position.

Being accustomed to associate the idea of the zinc pole, in a Voltaic series, with the end terminated by zinc, and the copper pole, with the end terminated by copper, I was surprised to find that, in decomposing water, the oxygen was attracted by the wire connected with the copper end of the deflagrator, while the hydrogen went to the wire connected with the zinc end. Subsequently, however, it occurred to me, that, in the deflagrator, the zinc pole is terminated by copper, the copper pole by zinc—and hence the apparent anomaly, that oxygen appears to be attracted by copper, and hydrogen to be attracted by zinc.

The projection from the carbon, exposed between the poles, takes place at the negative pole of the pile, and not at the positive pole, as you have alleged; and thus your observation, that the current of igneous matter, is from the copper to the zinc, may be reconciled with the Franklinian theory.

The observations, which are the subject of this communication, combined with those which you have made, of the incapacity of the deflagrator, and Voltaic series in the usual form, to act, when in combination with each other—must justify us, in considering the former, as a Galvanic instrument, having great and peculiar powers.

Since the above was written, I have tried my series of three hundred pairs. The projectile power, and the shock, were proportionally great, but the deflagrating power was not increased in proportion. The light was so intense, that, falling on some adjacent buildings, it had the appearance of sunshine.

Having had another series of three hundred pairs made for Dr. Macneven of New York, on trying it, I connected it with mine, both collaterally, and consecutively, so as to make in the one case a series of six hundred, in the other a series, of half that number, but equal in extent of surface.—The shock of the two, consecutively, was apparently doubly as severe, as the shock produced by one; but the other phenomena seemed to me nearly equally brilliant, in either way.

The white globules which you noticed, were formed copiously on the ignited plumbago, especially in vacuo. I have not had leisure, to test them, being arduously occupied, in my course of Lectures, and in some efforts to improve the means of experimental illustration.

Since this letter was published, I find, that my friend Dr. De Butts of Baltimore, has, in one apparatus, availed himself of that alternation of surfaces, that omission of insulation, which I had first used in one of my Calorimotors;* in another more numerous series of smaller plates, he employs the principle of simultaneous immersion, originally used, with respect to an extensive series, in my Deflagrator. His plates differ from mine, in being semicircular—and there are more pairs in the series, and fewer large plates in each pair, than in the Calorimotor.† In his apparatus, the plates, by a quarter revolution, enter the acid: in mine, a similar movement in the trough, throws the acid on the plates.

I often contemplated the mode which he has adopted, as it seemed sufficiently convenient; but, for several reasons, preferred the methods which I have employed. Cutting the sheets semicircularly, is very wasteful of the metal—and I have never seen sheet zinc, for sale, in the circular form, nor copper either, unless for bottoms, which are too heavy and expensive. Plates of cast zinc cannot be used advantageously,

* Of which a Plate is given, at the end of the book.

† I consider two heterogeneous metallic surfaces, as for instance, one surface of copper and one surface of zinc, when associated by metallic contact, or a metallic strap passing from one to the other, as a Galvanic Pair—whether the surfaces be in one sheet of zinc, and one sheet of copper, or, consist of several sheets of zinc, and several of copper; one metallic communication uniting all the zinc sheets—and another, uniting all the copper sheets.

as they are too heavy for large apparatus, and are soon made rough by corrosion, which diminishes their energy; whereas the rolled zinc may be eaten down as thin as paper, and still be efficient. The rationale of this difference, is to be found in the crystalline texture of the cast zinc, which rolling destroys. That solution, to a certain extent, tends to expose the angles of crystals, has been fully shown, in the decrystallization of alum, first observed, I believe, by Mr. Daniels. I have recently seen it strikingly exemplified.

Experience demonstrates the importance, of encasing each zinc plate, especially if uninsulated, in the copper of the pair, which succeeds it, in the series. In the form adopted by Dr. De Butts, the copper cases cannot be made, without a much greater expense in the workmanship. Those which I have used, are formed by machinery, so that they are very handsomely finished, with great rapidity, and all of one size, and shape.

In consequence of this contrivance, a workman has undertaken to furnish Deflagrators, at forty-five or fifty cents for every Galvanic pair (seven inches by three) contained in them. This is much lower than the Paris prices, for apparatus far less powerful.

I cannot discover the motive of Dr. De Butts, for having the legs of his apparatus of glass—while, from the construction of his troughs within, he evidently sanctions my plan, of omitting insulation. Had I seen the glass legs, without being aware of the internal construction of his battery, I should have expected to find the inside partitioned by glass.

Dr. De Butts speaks of the coils of Col. Offerhaus and Mr. Pepys, as if that form of the Galvanic battery had originated with them; whereas this was one of the forms, first contemplated by me—it was afterwards actually made by Dr. Patterson and Mr. Lukens, and in a much larger form by Mr. Peale and Mr. Wetherill,* at least a year, I believe two years, before it was resorted to either by Pepys, or Offerhaus.

* See Memoir on a New Theory of Galvanism, Silliman's Journal, Vol. I. page 118—also Memoir on the Deflagrator, page 41.

[It may be proper to inform the reader, that the references made by the authors, from whom the following pages are taken, will be exchanged for, or coupled with, references to such portions of the Lectures, printed in this Supplement, as may substantially convey the same ideas, as the passages to which the authors have referred.]

PROFESSOR OERSTED'S

THEORY OF ELECTRO-MAGNETISM:

*As briefly stated by him in his first paper, giving an account of his discoveries.**

THE first allusion to his Theory, is made in the following paragraph:—

"The opposite ends of the Galvanic battery were joined by a metallic wire, which, for shortness sake, we shall call the *uniting conductor,* or the *uniting wire.* To the effect which takes place in this conductor and in the surrounding space, we shall give the name of the *conflict of electricity.*"

He afterwards proceeds to say:—

"We may now make a few observations towards explaining these phenomena.

"The electric conflict acts only on the magnetic particles of matter. All non-magnetic bodies appear penetrable by the electric conflict, while magnetic bodies, or rather their magnetic particles, resist the passage of this conflict. Hence they can be moved by the impetus of the contending powers.

* See Annals of Philosophy, vol. 16, p. 276.

"It is sufficiently evident from the preceding facts* that the electric conflict is not confined to the conductor, but dispersed pretty widely in the circumjacent space.

"From the preceding facts we may likewise collect that this conflict performs circles; for without this condition, it seems impossible that the one part of the uniting wire, when placed below the magnetic pole, should drive it towards the east, and when placed above it towards the west; for it is the nature of a circle that the motions in opposite parts should have an opposite direction. Besides, a motion in circles, joined with a progressive motion, according to the length of the conductor, ought to form a conchoidal or spiral line; but this, unless I am mistaken, contributes nothing to explain the phenomena hitherto observed.

"All the effects on the north pole above mentioned are easily understood by supposing that negative electricity moves in a spiral line bent towards the right, and propels the north pole, but does not act on the south pole.—The effects on the south pole are explained in a similar manner, if we ascribe to positive electricity a contrary motion and power of acting on the south pole, but not upon the north. The agreement of this law with nature will be better seen by a repetition of the experiments than by a long explanation. The mode of judging of the experiments will be much facilitated if the course of the electricities in the uniting wire be pointed out by marks or figures.

"I shall merely add to the above that I have demonstrated in a book published five years ago that heat and light consist of the conflict of the electricities. From the observations now stated, we may conclude that a circular motion likewise occurs in these effects. This I think will contribute very much to illustrate the phenomena to which the appellation of polarization of light has been given."

* See Lectures on Electro-magnetism, pages 54, 55, and 59, 60.

A SKETCH OF M. AMPERE'S

THEORY OF ELECTRO-MAGNETISM:

As given in the Annals of Philosophy, by an anonymous correspondent.*

"M. Ampere commences by assuming the existence of two electric fluids, according to the theory which is now general, I believe, in France. There appears to be no doubt about his meaning on this point, for though he uses the term electricity very frequently, and in a way which might be understood, perhaps, as applying equally either to a particular state of a body, or to a particular fluid existing among its particles, yet by the use of the term *electric fluids* in one place, and by the mention of electric currents as currents of matter, it is nearly certain that M. Ampere means to speak of electricity as consisting of two distinct fluids, which, though the one is called positive, and the other negative electricity, are to be considered as equally positive in their existence, and possessed of equal powers.

"The Voltaic battery is considered as an instrument possessing the power of conveying one of these electricities to the one end, the other to the other end. That which goes to the zinc end of the battery is called positive electricity; that which goes to the copper end negative: these names being retained, it may be presumed merely in deference to custom, and not because they have any reference to particular qualities of either the one or the other fluid.

"When a metallic wire is made to touch the two poles of a Voltaic battery, being a conductor of electricity, it carries off the two fluids; but the battery having within itself the power of continually conveying fresh portions of the fluids to the two extremities, the first portions that are removed by the wire are succeeded by others, and thus currents are produced, which are constant as long as the battery remains in action, and the poles continue connected by the wire. Now as it is in this state that the wire is capable of affecting the magnetic needle, it is very important for the exact comprehension of the theory that a clear and precise idea of its state, or of what is

* For February 1822.

assumed to be its state, should be gained, for on it in fact the whole of the theory is founded. Portions of matter in the same state as this wire, may be said to constitute the materials from which M. Ampere forms, theoretically, not only bar magnets, but even the great magnet of the earth; and we may, therefore, be allowed to expect that a very clear description will first be offered of it. This, however, is not the case, and is, I think, very much to be regretted, since it renders the rest of the theory considerably obscure, for though certainly the highly interesting facts discovered by M. Ampere could have been described, and the general laws and arrangements both in conductors and magnets stated with equal force and effect without any reference to the internal state of the wire, but only to the powers which experiment proves it to be endowed with, yet as M. Ampere has chosen always to refer to the currents in the wire, and in fact founds his theory upon their existence, it became necessary that *a current* should be described.

"At p. 63, vol. xv. Annales de Chimie, M. Ampere, while speaking of the battery and connecting wire, says, it is generally agreed that the battery continues to convey the two electricities in the two directions it did at the moment the connexion was first completed; "so that a double current results, the one of positive electricity, the other of negative electricity, parting in opposite directions from the points where the electromotive action exists, and reuniting in that part of the circuit opposed to those points."—This reunion would, of course, take place in the wire, and one may be allowed to ask, whether the magnetic effects depend on it, as M. Oersted seems to think, who calls it the electric conflict, and also what becomes of the electricities that accumulate in the wire. But from other parts of M. Ampere's memoirs, a very different idea of the electric currents may be gained; the one electricity is considered as continually circulating in one direction; while the other electricity circulates and moves in a current in the opposite direction, so that the two electricities are passing by each other in opposite directions in the same wire and apparatus.

"Without, however, dwelling on the state of the wire when thus circumstanced, M. Ampere is content, in order to avoid confusion, when speaking of the direction of the electrical currents, to wave attention to the two, and to speak as if there were but one only, which is to be called the electrical current, without any reference to positive or negative, and which is considered as moving in the battery from the copper to the zinc end, and in the wire from the zinc to the copper end. It is evident that thus modified, the existence of the current, and its direction, are assumed simply for the convenience of having something to which the direction of the electro-magnetical motions may readily be referred; and, consequently, when thus spoken of, no reference is made to the way in which the double current exists in the wire, or to the cause of the production of magnetism by it.

"In the historical sketch* I have already given of the facts as they were discovered, I mentioned that M. Oersted first ascertained the mutual action of the wire and the magnetic needle. He showed that the apparatus had power over the needle only when the connexion was completed, consequently the electricity must be in progressive motion, or forming a current, as M. Ampere states, before it can become magnetic. M. Ampere, then, discovered the fact that two electrical currents (using the word in his own sense) were capable of acting on each other, and producing entirely new electrical phenomena. This discovery was noticed in the former part of this letter,† and it was mentioned that when the currents were in the same direction, they attracted each other; when in different directions, they repelled each other. These attractions and repulsions differ entirely from those exhibited by electricity in a state of tension, as may be seen by referring back to the account given of them. M. Ampere nevertheless considers them as belonging to the electricity, but only when it moves in currents. They are, he thinks, dependent on certain properties which these currents possess, and are not produced by the action of any magnetic or other fluid which the electricity has set at liberty. Electricity, when accumulated, has the power of causing certain attractions and repulsions which are called electrical; when in motion it has the power of causing certain other attractions and repulsions; namely, those in question.

"Having then ascertained these new properties of electric currents, M. Ampere, in the progress of his reasonings, reverted back to Oersted's experiment, and removing one of the currents, he substituted a magnet in its place. The results were the same as before; the attractions and repulsions were of the same kind, and took place in the same manner; so that the effects which were known to be electrical with the two wires, were produced, when in place of one of them a magnet was used: only, the distribution of the powers in the magnet seemed to differ from that in the wire or current; for that power which is exhibited by one side of the wire is concentrated in one end of the magnet, and that power exhibited by the other side of the wire in the other end.

"On taking away the remaining wire, and substituting a second magnet for it, the two acted in the usual manner; but the action was found to be analogous to that of two electrical currents. So that M. Ampere was forced by his experiments, and the view he had taken of them, to conclude, that all the attractions, whether excited by two wires, a wire and a magnet, or

* The necessity of referring to this historical sketch, is superseded by that, given in this Supplement, page 53.

† *Annals of Philosophy, vol. ii. p. 275, New Series.* See Lectures on Electro-magnetism, page 55, 2d paragraph.

two magnets, were purely electrical, and, in fine, that all magnetic phenomena are occasioned by electric currents.

"Taken in this point of view, electricity and magnetism are identical, or rather, magnetic phenomena are a series of electrical phenomena. Hence magnetism should form a branch of electricity under the head of electrical currents; but before we dispose of it in this premature, though convenient, manner, we should endeavour to state what the arrangement of electrical currents are which M. Ampere has found it necessary to assume to account for the various known phenomena of magnetism.

"The arrangement of magnetic power in a conducting wire is so different to that in a magnet, that it is not at first very evident how the one may be considered as convertible into the other. Currents of electricity, according to the theory, were essentially necessary to the production of magnetic phenomena, but where are the currents in a common magnet? It was a bold thought to say they actually existed in it, but M. Ampere has ventured the idea, and has so arranged them, theoretically, as to account for very many magnetic phenomena.

"A magnet, M. Ampere says, is an assemblage of as many electric currents moving in planes perpendicular to the axis, as there may be conceived lines, which, without cutting each other, form closed curves; for, he says, it seems impossible to him from the simple consideration of the facts, to doubt that there are really such currents round the axes of magnets; and magnetization consists, he says, in an operation by which there is given to the particles of steel the property of producing in the direction of the currents before spoken of, the same electromotive action which is found in the Voltaic pile, the electric calamine of mineralogists, the heated tourmaline, and even in the pile formed of moistened paper, and disks of the same metal at different temperatures.

"With regard to the extent of the curves which these currents travel through, the theory has not yet decided whether it relates to the whole magnet, or to the particles of which it is formed. If a section of a magnet perpendicular to its axis be conceived, the currents situated in it may either be concentric, in which case they will vary gradually in extent, or they may exist round each particle, in which case they are of uniform size, but very minute. It appears from calculation that either of these arrangements would account for the phenomena. M. Ampere is, I believe, inclined to adopt the latter.*

"Conceiving a magnet then to be formed in this way of electric currents, and reverting to the experimental results obtained by the action of a wire and a magnet on each other, if one end of the magnet be presented to one

* *Journal de Physique, xcii.* 163.

side of the wire, it will attract it; if to the other side, it will repel it. The reason according to the theory is evident: the currents pass in different directions on the two sides of the magnet, up on one side, down on the other. When that side is towards the wire in which the currents move in the same direction as in the wire, attraction takes place; when the opposite side is towards the wire, repulsion takes place, because the currents are in opposite directions. If the magnet be turned round, and the other pole be brought near the wire, the direction of the currents in the magnet will be turned also, and motions opposite to those which before took place will now occur, because the place of the similar and dissimilar currents has been changed.

"In consequence of the idea which had been formed of a magnet as an assemblage of electric currents in planes perpendicular to the magnetic axes, M. Ampere endeavoured to obtain an imitation by forming a spiral or helix of wire, and passing a current of electricity through it. As the electricity traversed the spirals, it would nearly resemble the different currents in the magnet; and the effect of the obliquity of the spirals was counteracted by returning the wire from the extremity down the axes of the helix. This instrument has been described before,* and the similarity of the effects produced by it to those of the magnet stated.

"Naturally led by his elaborate views to substitute terrestrial magnetism for the magnet he had previously used in experiments on the wire, M. Ampere was induced to suspend a circle very delicately, in hopes the earth's magnetism would make it traverse; for as according to his theory, wire and magnets moved each other, not by any supposed pole or point of attraction and repulsion, but by the attraction and repulsion of the currents passing through them, he hoped to be able to make a current move also by those he assumed to exist in the earth. The success of this experiment has been related,† and was certainly sufficient to make the author trust very confidently to a theory which had guided him so safely to such novel and important results.

"The traversing of the curve by the magnetism of the earth added another argument to those in support of M. Ampere's theory. If the experiment had not succeeded, the distinction between the curve and the needle would have been fairly urged against the theory; as it succeeded, it admits of being adduced as another proof that currents in curves such as those M. Ampere assumes to exist in the magnet, are sufficient to account for the phenomena presented by it. But the important conclusion M. Ampere ar-

* *Annals of Philosophy, ii.* 281, *New Series.* See Lectures on Electro-magnetism, page 56, last paragraph.

† *Annals of Philosophy, ii.* 279, *New Series.* See Lectures on Electro-magnetism, page 56, 5th paragraph.

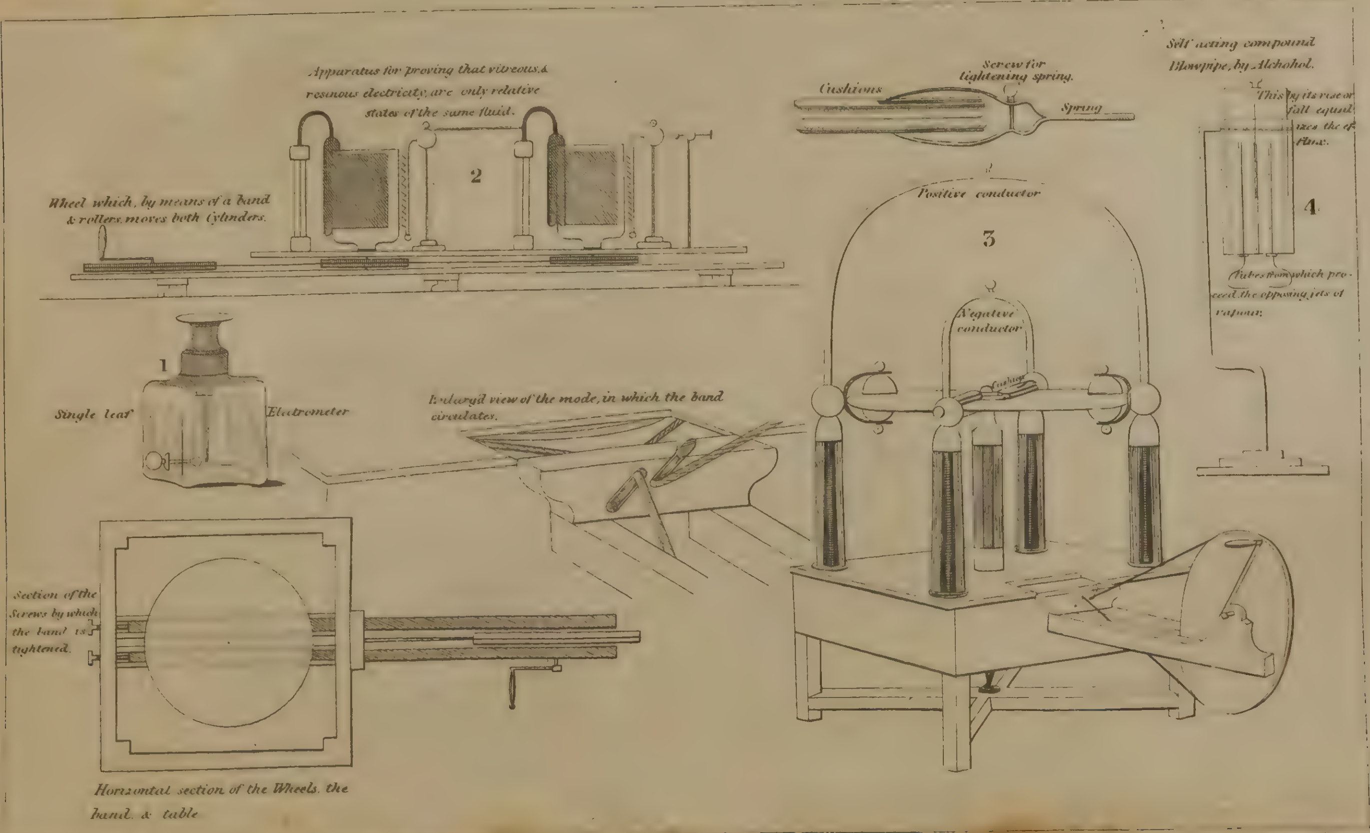
rives at from it is, that the magnetism of the earth is itself caused by currents of electricity, which, moving from the east towards the west round the globe are at right angles to the magnetic meridian. These currents, if they exist, are compared to those which would be found in a Voltaic battery if its two extremities were made to meet. There is nothing probably in the globe which can be compared to the continuous conductor formed by the metallic wire, but M. Ampere has shown that the battery itself is magnetic; and he supposes it probable that the arrangement of the materials of the globe may be such as to constitute a battery existing like a girdle round the earth, which, though composed of comparatively weak elements, is sufficiently extensive to produce the effects of terrestrial magnetism. Its irregularity in that case would account for the distorted forms of lines of similar variation, and the changes that take place in it would explain the change of the direction of the needle. Some general action, however, is supposed to exist which aids in producing the currents of electricity, and in a direction approaching parallelism with the equator; and the variation is supposed to depend on the progress of oxidation in the continental regions of the earth.

"The diurnal variation is considered as dependent on the diurnal change of temperature in the superficial electromotors of the globe. The various strata of magnetic materials are considered as so many Voltaic piles.

"Supposing that electric currents actually exist in the masses of matter which form the planetary and stellar globes, M. Ampere suggests the possibility that they may sometimes be so powerful as to make the heat which is necessarily excited rise to ignition. In this case, a permanent incandescence with a brilliant light would be produced without either combustion or loss of substance. "May we not suppose," says M. Ampere, "that the opaque globes are so only because of the small degree of energy in the electric currents established in them, and find in the more active currents the cause of the heat and light of those globes that shine by themselves."

"I must again say, that having assumed the existence of two distinct electric fluids, and the identity of electricity with magnetism, I think the first part of the theory by no means sufficiently developed. M. Oersted has, in this respect, aimed at more perfection than M. Ampere; with what success, it is not necessary for me to determine."

FINIS.


Apparatus for proving that vitreous & resinous electricity are only relative states of the same fluid.
2
Wheel which, by means of a band & rollers, moves both Cylinders.
1
Single leaf
Electrometer
Enlarg'd view of the mode, in which the band circulates.
Section of the Screws by which the band is tightened.
Horizontal section of the Wheels, the band, & table
Cushions
Screw for tightening spring.
Spring
Positive conductor
3
Negative conductor
Self acting compound Blowpipe, by Alchohol.
4
Tubes from which proceed the opposing jets of vapour.

EXPLANATION OF THE OPPOSITE PLATE.

Explanation of the Calorimotor.

A *a*, Fig. 1st, two cubical vessels, 20 inches square, inside. *b b b b* a frame of wood containing 20 sheets of copper, and 20 sheets of zinc, alternating with each other, and about half an inch apart.—T T *t t* masses of tin cast over the protruding edges of the sheets which are to communicate with each other. Fig. 2, represents the mode in which the junction between the various sheets and tin masses is effected. Between the letters *z z* the zinc only is in contact with the tin masses. Between *c c* the copper alone touches. It may be observed, that, at the back of the frame, ten sheets of copper between *c c*, and ten sheets of zinc between *z z*, are made to communicate, by a common mass of tin extending the whole length of the frame, between T T: but in front, as in fig. 1, there is an interstice between the mass of tin connecting the ten copper sheets, and that connecting the ten zinc sheets. The screw forceps, appertaining to each of the tin masses, may be seen on either side of the interstice: and likewise a wire for ignition held between them. The application of the rope, pulley, and weights, is obvious. The swivel at S permits the frame to be swung round and lowered into water in the vessel *a*, to wash off the acid, which, after immersion in the other vessel, might continue to act on the sheets, encrusting them with oxide. Between *p p* there is a wooden partition which is not necessary, though it may be beneficial.

Explanation of Figure 3 and Figure 4.

Fig. 3, represents an apparatus analogous to a Couronne des Tasses, but reduced to a form no less compact than that of the trough; hollow parallelopipeds of glass are substituted for tumblers or cells. The plates are suspended to bars counterpoised like window sashes.

The apparatus of 300 pairs, alluded to in the first memoir on the Galvanic Deflagrator, was of the construction here represented. I have since arranged the glass parallelopipeds, in a trough, by the partial rotation of which they are filled and emptied.

*** *Explanations of the other Plates are engraved upon them.*

CALORIMOTOR.

Plate XV

Fig. 1.

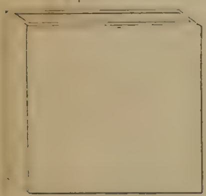


Fig. 1.

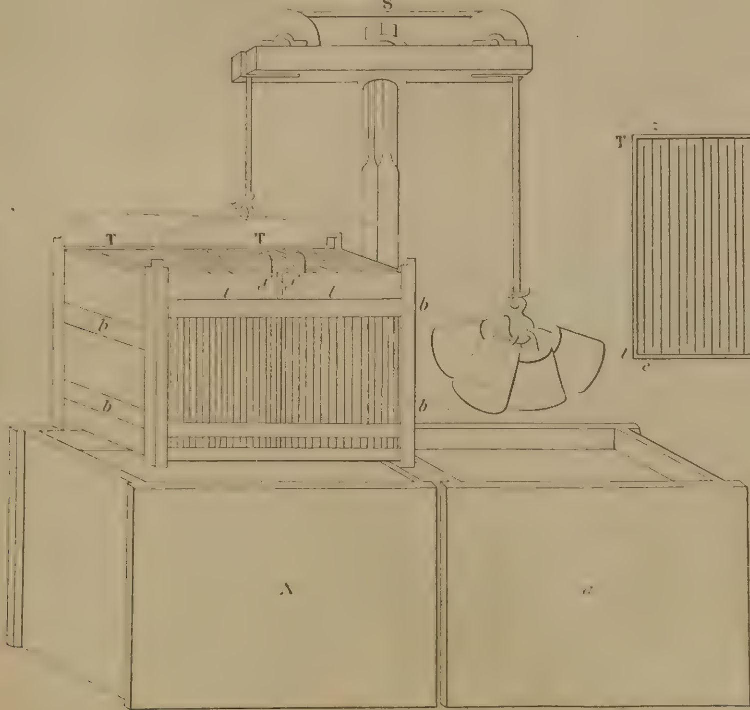


Fig. 2.

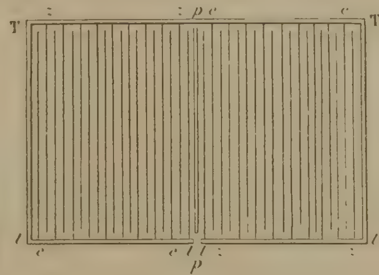
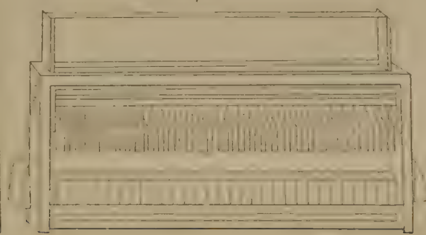


Fig. 3.



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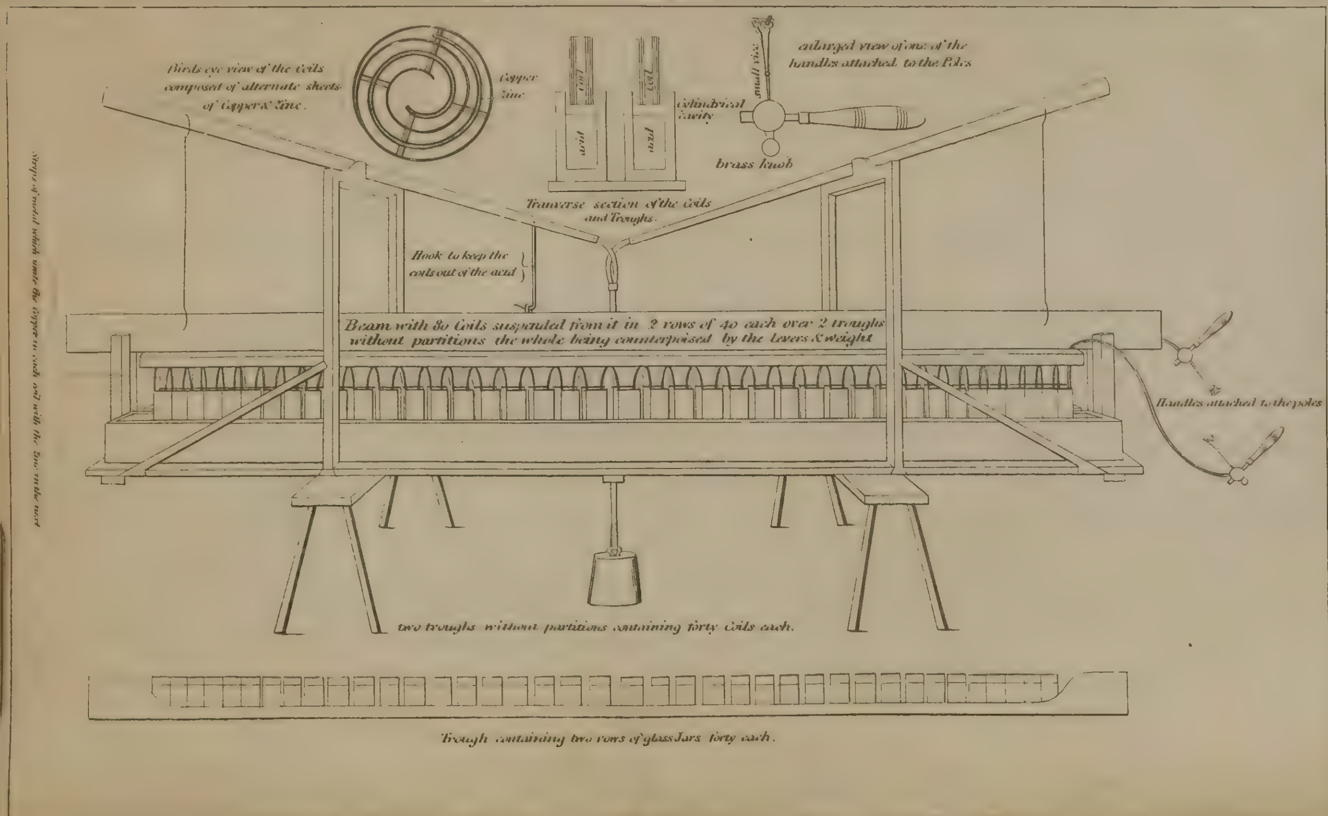
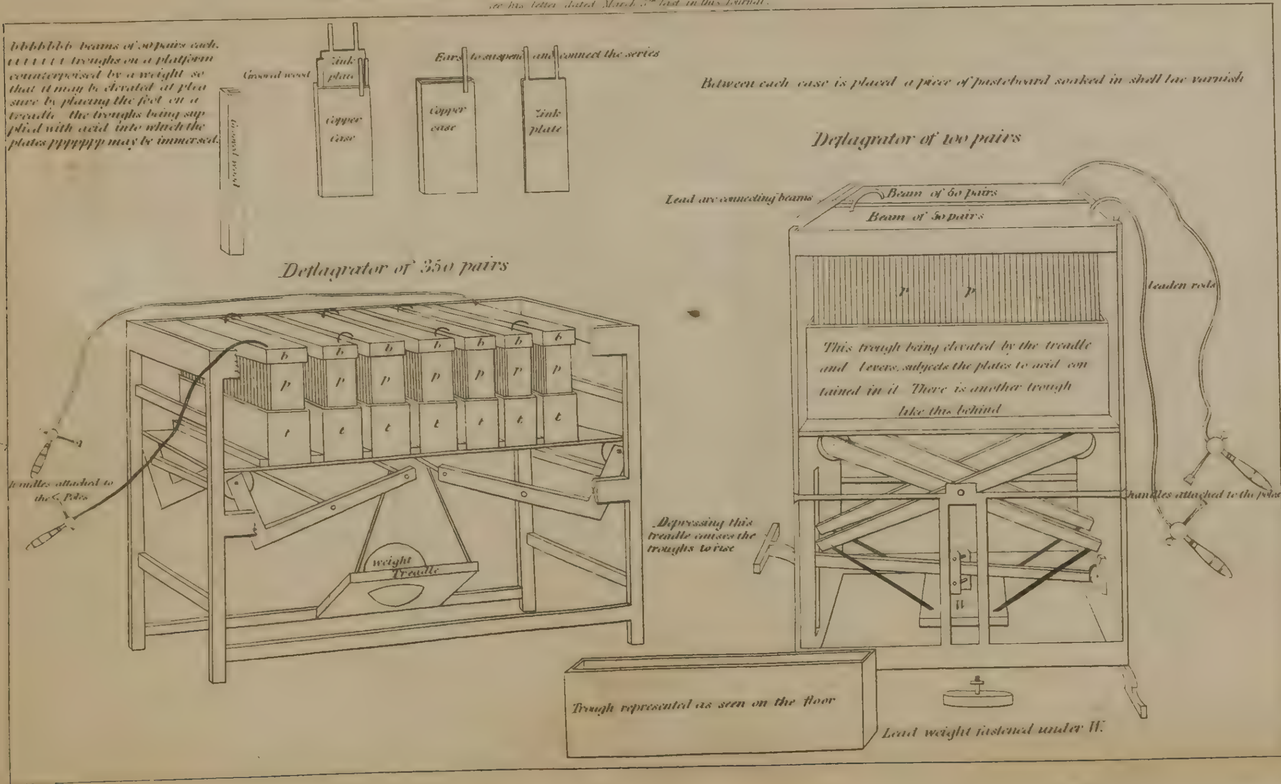
DR. HARE'S GALVANIC DEFLAGRATOR.

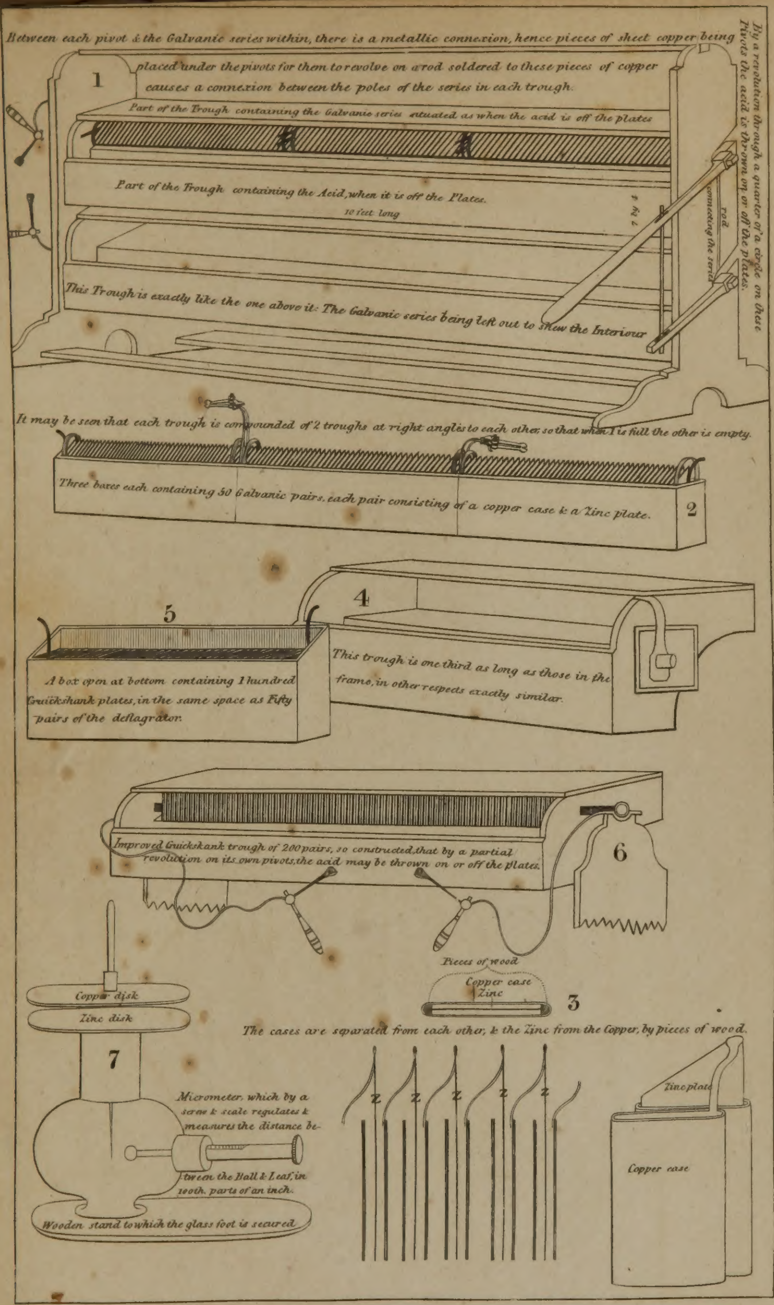


DR. HARE'S NEW GALVANIC DEFLAGRATORS.

see his letter dated March 5th last in this Journal.



AND IMPROVED DEFLAGRATORS BY DR. HARE.



Mr. Amsterdam